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BACKGROUNDER

JOINT FEDERAL STUDY HIGHLIGHTS LEVELS AND EFFECTS OF CHEMICALS FOUND IN THE GREAT LAKES ECOSYSTEM BASIN

- The report Toxic Chemicals in the Great Lakes and Associated Effects is a comprehensive review of the scientific knowledge of the levels of toxic chemicals in the Great Lakes basin and their effects on human health, fish and wildlife. The joint report was prepared by Environment Canada, Health and Welfare Canada and the Department of Fisheries and Oceans.

- This report will become the scientific reference for information on toxic chemical levels and effects in the Great Lakes basin. It will be used to focus the actions the Federal Government will be undertaking through the Great Lakes Action Plan and the Federal Government's Green Plan for Canada.

- The Government of Canada is commited to a leadership role on health and environment issues. It is essential that all sectors of society move to reduce contamination of the environment. The goal of virtual elimination of persistent toxic substances in the Great Lakes basin can only be achieved if there is a change in attitude and behaviour on a broad scale.

- The major findings of the report include:

  - Levels of contaminants in Great Lakes fish and aquatic birds have decreased substantially for the high levels reported in the 1970s but have remained relatively constant since the early 1980s.

  - Municipally-treated drinking water drawn from the Great Lakes contains minute quantities of contaminants but the amounts rarely exceed current guidelines for Canadian drinking water quality.

  - Some stocks of fish have levels of toxic substances which exceed the levels set by Health and Welfare Canada. Commercial fisheries for these stocks are closed or controlled, and sport fisheries are governed by provincial consumption advisories.

  - Wildlife studies in the Great Lakes basin show that developmental and reproductive effects can occur in various species exposed to toxic chemicals including birds, reptiles, fish and mammals.

/...2

- In the last decade there have been significant recoveries in reproductive success for most of the previously affected bird species. Serious problems are now confined to a few highly contaminated areas.

- Canadians living in the Great Lakes basin do not have higher contaminant levels in their tissues than people in other parts of North America. However, individuals consuming large amounts of contaminated fish and wildlife, especially native peoples and sportspersons, are likely to have a greater than average exposure to several persistent pollutants.

- Elevated levels of contaminants in the Great Lakes basin do pose a threat to human health, but the precise nature and extent of the threat is unclear. Residents of the basin consuming large quantities of contaminated fish and wildlife should reduce their intake in accordance with current advisories.

- Nursing infants of mothers who consume large quantities of contaminated fish and wildlife can be exposed to greater than average amounts of contaminants from their mothers' milk. However, the advantages of breast-feeding outweigh the disadvantages to the infant.

For additional copies contact:

Environment Canada
Great Lakes Environment Office
25 St. Clair Avenue East, 6th Floor
Toronto, Ontario
M4T 1M2

Health and Welfare Canada
Publications Distribution Centre
19th Floor
Jeanne Mance Building
Tunney's Pasture
Ottawa, Ontario
K1A 0K9

Department of Fisheries and Oceans
Communications Directorate
Bayfield Institute
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario
L7R 4A6

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Health Protection Branch

ISSUES

THE GREAT LAKES
ACTION ON HUMAN HEALTH CONCERNS NOW

GREAT LAKES HEALTH EFFECTS PROGRAM

- *1990-95 Federal Program starting January 1990*
- *In partnership with the public and communities around the Great Lakes Basin*
- *Budget: 20 million dollars over 5 years*
- *Part of the Great Lakes Action Plan, which also provides a Great Lakes Cleanup Fund and a Preservation Program*
- *Required by the Great Lakes Water Quality Agreement (1987 Protocol) signed by Canada and USA*
- *Administered by Health and Welfare Canada (Environmental Health Directorate) with other Departmental participation*

THE PUBLIC	*through polls, consultation meetings*
RESEARCHERS	*through Workshops, studies*
REGULATORS	*through binational Agreements*
...SAY THAT:	***• There are risks to health***
	• The extent is unknown
	• It is time to act now

THE GREAT LAKES BASIN IS HOME, WORKPLACE, COMMUNITY FOR OUR FAMILIES...NOW AND IN THE FUTURE

The Great Lakes Basin:

- *contains 20% of the world supply of fresh water*
- *is one of the most densely populated and industrialized regions in North America*
- *contains over 800 identified chemicals, only 300 of which can be evaluated with available information*
- *provides major economic and social underpinning for residents (industry, recreation, drinking water, transportation, food)*

ACTIVITIES OF THE HEALTH EFFECTS PROGRAM:

- ***A HEALTH FOCUS AND RESOURCE FOR THE PUBLIC*** *throughout the Great Lakes Basin and especially in "Areas of Concern" where Remedial Action Plans (RAPs) are under development.*

- ***PUBLIC CONSULTATION*** *with an emphasis on ongoing public participation and the sharing of information. Through a public advisory committee to the Program, community meetings, media reports of health effects data and action plan options, collaboration with various non-government sectors, etc. the Program becomes a resource for public and private action.*

- ***JOINT CANADIAN/AMERICAN OBJECTIVES*** *for specific contaminants and the ecosystem that are fully protective of health.*

- ***HEALTH INDICATORS*** *to help measure progress in environmental cleanup and preservation, such as the monitoring of contaminants in human tissue.*

- ***IDENTIFY POPULATIONS AT RISK*** *from exposures to contaminants from air, water, soil, food, and/or consumer products and provide ways for these groups to reduce the risks to their health.*

- ***STUDIES*** *on the health implications of contaminants in the Great Lakes Basin which are solution oriented. This includes research (with findings available to the public) on such concerns as birth defects, cancer, childhood development, and respiratory health.*

FOR INFORMATION AND PARTICIPATION CONTACT:

Great Lakes Health Effects Program,
Health and Welfare Canada,
Environmental Health Centre
Room 136,
Tunney's Pasture,
Ottawa, Ontario
K1A-0L2

Dr. Andy Gilman or Mary Hegan
(613) 957-1876

This is one of the Health Protection Branch Issues produced by the Health Protection Branch of Health and Welfare Canada for the public, media and special interest groups interested in health protection in Canada.

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Health and Welfare Canada
Santé et Bien-être social Canada

Health Protection Branch
Direction générale de la protection de la santé

BACKGROUNDER

GREAT LAKES HEALTH EFFECTS PROGRAM RELATED INFORMATION MATERIALS

The following information can be obtained from:

Great Lakes Health Effects Program
Environmental Health Directorate
Health Protection Branch
Health and Welfare Canada
Environmental Health Centre
Room 136,Tunney's Pasture
Ottawa, Ontario, KlA 0L2

Telephone 613-957-1876
FAX 613-952-9798

1. a) **Toxic Chemicals in the Great Lakes and Associated Effects -Synopsis** - this interdepartmental report by Environment Canada, Health and Welfare Canada and the Department of Fisheries and Oceans is a comprehensive review of the scientific knowledge of the levels of toxic chemicals in the Great Lakes basin and their effects on human health, fish and wildlife.

   b) **Toxic Chemicals in the Great Lakes and Associated Effects -Technical Vols. 1 and II** - It is a two volume 755 page compendium of scientific data on levels of toxic chemicals in human tissue, wildlife, fish, water, sediment and soil and an evaluation of their implications for human health and the ecosystem. It is directed at a technical audience.

2. **Clean Waters - Toward a Healthy Great Lakes - St. Lawrence Ecosystem** - this brochure is produced to help you understand some of the problems facing the Great Lakes-St. Lawrence ecosystem, especially pollution by toxic substances. It also explains what is being done, particularly by the Canadian Government, to clean up and restore this ecosystem to a healthy state.

3. **Health Protection Branch - Issues** (produced for the public, media and special interest groups interested in health protection in Canada)

.../2

a) **The Great Lakes Action on Human Health Concerns Now - Great Lakes Health Effects Program (GLHEP)**- this paper provides a brief outline of the GLHEP, providing some facts on the Great Lakes Basin, and an outline of the activities of the health effects program.

b) **Dioxins and Furans** - this paper discusses the chemical make-up, results of exposure, exposure levels, and what is being done about these undesirable environmental contaminants.

c) **PCBs and Human Health** - this paper discusses where PCBs are found, exposure and health effects and what is being done about PCBs.

d) **Drinking Water Guidelines** - this paper discusses water supply contaminants, the basis for the guidelines and what the guidelines mean in terms of health.

e) **Health Effects of Acid Air Pollution** - this paper discusses pure air versus polluted air, breathing easily, the search for causal connections and proceeding with caution.

f) **Food Chemical Contaminants - Assessing Health Risks** - this paper provided information on determining tolerable daily intake, determination of probable daily intake, and comparing the tolerable daily intake with the probable daily intake.

4. **Control of Pesticide Residues in Food** - "Dispatch No. 51", discusses how the Health Protection Branch of Health and Welfare Canada, under authority of the Food and Drugs Act is charged with the responsibility of ensuring that foods offered for sale to Canadians are fit for consumption in that they are safe, clean and unadulterated.

5. **Risks of Dioxins and Furans to Human Health** - an Information Letter directed at doctors, provides information on animal studies, human studies, exposure assessment and vulnerable groups.

6. **Health Risk Determination - The Challenge of Health Protection** - this publication is intended to help us understand the federal government's role in health risk determination and how we all must make the final decisions to use or consume products whose risk has been determined to be acceptable.

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BACKGROUNDER

"TOXIC CHEMICALS IN THE GREAT LAKES AND ASSOCIATED EFFECTS" COMPARISON OF CONCLUSIONS AND ACTIONS RELATING TO THE HEALTH ASPECTS OF THE REPORT

Technical Report Conclusions (Health Chapters)	Activities Underway (Department of National Health and Welfare)
A.VOLUME II - EFFECTS	
1.The major route of exposure to the IJC's Critical Pollutants is through the consumption of food, and in particular fish and wildlife from the Great Lakes. Exposure to the Critical Pollutants from breathing the air and drinking or bathing in the water is not likely to exceed 10-15% of the total exposure.	1(a) Market basket survey of contaminants in food supplies within the Great Lakes basin and nationally. (b) A cooperative program with native peoples in the Great Lakes basin to determine intakes of contaminants through consumption of fish and wildlife. (c) Monitoring of food and air to identify potential problem with respect to contaminants. (d) Multi-media assessments of human exposure to and intake of contaminants in the Great Lakes basin as listed through Annex 1 of the Great Lakes Water Quality Agreement (1987 Protocol) and listed on the Priority Substances List of the Canadian Environmental Protection Act. (e) A study of the uptake of contaminants by skin to assess exposure during bathing and water based recreation.
2. The limited human tissue residue data available indicate that the general population residing in the Great Lakes basin is probably not exposed to higher levels of the Critical Pollutants than people residing elsewhere in North America. Some specific sub-groups within the basin who consumed contaminated fish or wildlife have higher than average levels of several persistent chemical contaminants. There are insufficient	2(a) Implementation of a Basin wide human tissue surveillance program to establish levels and trends over time and by regions. Includes priority sampling of high risk groups (such as sportsmen and native communities). (b) Development of a Canadian human tissue bank for long-term evaluation of human tissue levels.

Great Lakes Health Effects Program

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data to draw any conclusions about temporal trends of tissue residue concentrations in the general population residing in the Great Lakes basin. Wildlife studies have shown that contaminant levels in the basin have declined significantly in many areas since 1970 but now have equilibrated.

(c) Development and monitoring of biochemical markers in human populations to assess exposure and effects.

(d) Development of methodologies for determining levels of complex chemicals.

3. The limited number of published studies available indicate that rates of cancer incidence and mortality and adverse reproductive outcomes in the Great Lakes region are no higher than would be expected in any highly industrialized areas of the country. However, a more thorough assessment of the data is desirable. More information is needed about lifestyles and occupation before overall mortality and morbidity trends can be related to specific environmental exposures.

3(a) Extensive evaluation of cancer mortality and, for the first time, cancer incidence patterns for the Great Lakes basin.

(b) Extensive evaluation of congenital anomalies in the Great Lakes basin.

(c) Evaluation of hospitalization rates by community, township or region in the Great Lakes basin.

4. The limited data available do not permit a thorough assessment of the effect of toxic chemicals in the Great Lakes on human health. The few epidemiological studies available show an association between the maternal consumption of fish from Lake Michigan and adverse effects in developing children. These are important findings and require replication and validation. Despite the uncertainties associated with these studies and that it may be never be possible to unequivocally identify any single contaminant or mixture of contaminants as the cause of adverse health effects, it would be prudent to reduce the release of contaminants to the environment and thus reduce the potential for exposure and adverse human health effects.

4(a) Three population based studies using questionnaires to evaluate health effects in communities (general population, farming communities, native communities) and their relationship to contaminant exposure.

(b) Working with communities and providing advice to the general population and especially high-exposure groups (such as sportsmen and native communities) on ways to reduce intake of contaminants (sticking to advisories, changing habits, etc.).

(c) Providing advice to regulatory agencies responsible for reducing contaminant emissions to ensure quick, effective action is taken to protect human health.

5. Estimates of exposure for the general adult population to the Critical Pollutants are usually below established acceptable and/or tolerable intakes. These assume that fish consumption advisories are followed. Specific subpopulations residing in the Great Lakes basin that consume locally caught fish or wildlife, or who live in highly contaminated areas may be exposed to higher levels of toxic chemicals than the general population. Fetuses and breast-fed infants could be exposed to higher levels of contaminants than the general population through placental transfer and breast

5(a) Identifying specific populations in the Great Lakes basin which are most at risk because of higher than average exposure to contaminants or enhanced sensitivity (see three population studies mentioned in 4(a)).

(b) Increasing public awareness through teleconferences, posters, videos, information to medial practitioners and public meetings and proposing ways in which highly-exposed/highly-sensitive individuals can reduce the potential impact on their health.

milk. Although these exposures are for a relatively short period of time, they occur at a critical period in development. Other groups of individuals may be more sensitive to the effects of contaminants than the general population. In some cases, individuals may show a hypersensitive response to low concentrations of a range of chemical substances. In other cases individuals may be suffering from a disease that compromises their health. For example, individuals who have respiratory diseases may be at greater risk from the effects of airborne pollutants in the basin.

6. There is limited data to show that the Critical Pollutants are more likely to act in an additive manner, rather than synergistically. Since most exposure guidelines and standards are based on individual chemicals and not mixtures, exposure to all synthetic chemicals should be as low as possible. Standards and guidelines intended to protect human health should take account of concurrent exposure through all relevant pathways and the potential additive nature of the effects.

6(a) Toxicology studies that examine how mixtures of chemicals interact to exert an overall effect on successive generations (1 study), on behaviour (2 studies), on reproduction (1 study), on tumour promotion (1 study), on delayed nerve damage (1 study), on genetic mutation (1 study).

(b) Development of guidelines and standards are now based on total exposures from all sources. Ways to harmonize basin standards between jurisdictions in the basin are being developed, as are rational ways to develop guidelines and standards that address the potentially additive effects of mixtures.

7. Wildlife studies have shown that developmental and reproductive effects can occur in a wide range of species including birds, reptiles, fish and mammals exposed to mixtures of contaminants in the Great Lakes basin. While differences exist in behaviour and exposure between humans and wildlife, these findings suggest that these kinds of subtle health effects should be investigated in human populations.

7(a) Cooperative work with the Canadian Wildlife Service to evaluate the links between wildlife impacts and human health and to develop biochemical markers for humans and wildlife.

(b) Population and animal studies underway are focusing on subtle effects, e.g., reproductive, immune, behaviourial effects.

8. Highly exposed populations in the Great Lakes basin are at risk even if the nature and the extent of the threat to health are unclear. Resources and adequate appropriations are required for a long-term commitment for Great Lakes research to resolve the uncertainties associated with the implications for health of exposure to toxic chemicals and the means to reduce health risks.

8(a) The Great Lakes Health Effects Program is a five year commitment to identify populations "at risk" and to help them reduce their exposures.

(b) The population and animal studies underway (see 4(a) and 6(a)) are designed to determine the nature and extent of effects in human populations.

9. Studies are required to clarify effects of contaminants on human health in the Great Lakes basin and to improve remedial and regulatory strategies:

(a) The relative importance of different exposure pathways (air, drinking water, food, soil, fish) for a wider range of contaminants should be quantified for human populations residing in the Great Lakes basin. This should include accurate information on the types and amounts of fish consumed. There is also a need to establish an ongoing monitoring program for residues of toxic chemicals in human tissues of the residents of the Great Lakes basin. The program should provide data for temporal and spatial analyses of concentration trends and should be correlated with equivalent data from wildlife populations. Part of this should include the establishment of a comprehensive human tissue bank.

9(a) and (b)
The surveillance programs mentioned in 1(a), (b), (c) and 2(a), (b), (c) will address these needs. Work is underway now to help people reduce excessive exposures to contaminants (see 4(b) and 5(b)).

(b) Monitoring of human subpopulations thought to be at higher risk (developing fetuses, breast-fed infants, disease-compromised individuals and individuals consuming large amounts of Great Lakes fish or aquatic wildlife) is needed. If higher exposure (based on body burdens or estimates of intake) is confirmed then recommendations should be developed promptly to assist these groups to reduce their exposure.

(c) There is a need to develop more sensitive endpoints to measure adverse effects on the reproductive, immune and nervous systems in both human populations and animals to assess the effects of long-term, low level exposure to toxic chemicals. This will not only provide direction for researchers and regulatory officials but also for physicians who need guidance in the identification of environmentally induced disease.

(c) The development of biochemical markers and some of the studies that are evaluating subtle health effects will meet this need.

(d) Routine analysis for PCBs should be conducted on a congener-specific basis. Additional toxicity studies in laboratory animals using specific PCB congeners are required to permit meaningful hazard assessments of this large family of chemicals.

(d) Analyses of PCBs in food and tissue in wildlife, fish and humans is now including some congener specific analyses using newly developed methods and sophisticated equipment. Long-term animal exposure studies are underway with several PCB congeners to assess their toxicity. International collaboration is involved.

(e) Analyses for lead should include the identification of the lead species present because alkyl lead is at least 100 times more toxic than inorganic lead.

(e) Transfer of lead from the mother to the fetus is being evaluated. The effects of lead on male reproduction are also being assessed. Alkyl lead toxicity studies are complete. Analyses are not currently being carried out for lead in human tissue.

(f) Mercury occurs in food (primarily fish) and drinking water at low levels. Elevated blood levels in humans have been associated with adverse effects on the nervous system. Studies to determine whether more subtle effects are associated with long-term, low level exposure to mercury are needed.

(f) The delayed onset of loss of nerve endings is being evaluated in animals previously exposed to mercury.

(g) More information is needed on the interactive effects of toxic chemicals, particularly with respect to long-term, low-level exposure to mixtures.

(g) Interactive effects are being evaluated in sophisticated animal and human studies (see 6(a)).

B. VOLUME I - CONTAMINANT LEVELS AND TRENDS

10. Residents of the Great Lakes basin are exposed to hundreds of chemicals over a lifetime, many of which come from outside the region. Some of these chemicals have been detected in adipose tissue, blood, mothers' milk, liver, kidney, brain, muscle and gonads. Their presence in the environment and in human tissues confirms that there is exposure and bioaccumulation.

10. More sophisticated analyses and a comprehensive surveillance strategy will enable a better assessment of human tissue levels (trends overtime, by region or community, by gender and by age).

11. The majority of non-occupational exposure to environmental contaminants is through food, much of which is grown outside the basin. The precise proportion depends on many factors but is between 40 and nearly 100% for the

11. See activities listed under 1(a), (b), (c) and (d).

chemicals discussed in this report. Exposure through air, water and soil contribute smaller proportions, although exposure through soil is an important route for small children who inadvertently ingest large amounts.

12. The majority of exposure to environmental contaminants in food is from dairy products and meat. It is difficult to compare concentrations reported in different studies because of different definitions of "average diets" and because samples have been analyzed for different chemicals. Most of the studies on exposure from food are for an average adult and do not deal with infants and children, whose exposures are often larger (per unit body weight).

12. Foods are under constant surveillance and levels are extremely low. Standardized methods for evaluating intakes for adults, children, infants and newborns are in preparation.

13. Although the data are very limited and different studies cannot often be compared, it is unlikely that residents of the Great Lakes basin are exposed to higher concentrations of contaminants than people living elsewhere in Canada.

13. See activities listed under 1(a).

14. Levels of contaminants in adipose tissue are indicative of body burdens, but there are insufficient data to permit an assessment of temporal or spatial trends. However, levels in residents of the Great Lakes basin are no higher than those in residents of other regions of Canada. Levels of metals, especially lead, and PCBs have been determined in blood. These reflect recent exposures. Concentrations of contaminants in mothers' milk are important because they indicate loadings to nursing infants. It is difficult to determine spatial and temporal trends because historic data are inadequate and there are differences in sample collection and analysis.

14. See activities listed under 2(a).

FOR MORE INFORMATION ON THE ACTIVITIES UNDERWAY IN THE GREAT LAKES HEALTH EFFECTS PROGRAM CONTACT DR. ANDY GILMAN OR MARY HEGAN AT (613) 957-1876.

Toxic Chemicals in the Great Lakes and Associated Effects

Synopsis

Government of Canada Gouvernement du Canada

Toxic Chemicals in the Great Lakes and Associated Effects

SYNOPSIS

March 1991

Environment Canada

Department of Fisheries and Oceans

Health and Welfare Canada

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Summary of Significant Findings

The increased commercial production and widespread use of synthetic chemicals and metals since the 1940s have resulted in the contamination of the environment. While the presence of persistent toxic chemicals in the Great Lakes has been known for some time, concerns have been directed in recent years towards possible human health effects of these chemicals.

This report summarizes what is currently known about the levels and the effects of toxic chemicals in the water, sediments, fish, wildlife and human residents of the Great Lakes basin. A complete account of all the findings is provided in the two technical volumes of this report. The following are the most significant findings.

1. The concentrations of toxic chemicals in the open waters of the Great Lakes (in the low parts per trillion range) are within the objectives of the Canada-U.S. Great Lakes Water Quality Agreement (GLWQA). These objectives are set to protect the most sensitive user (aquatic biota), and are well below Canadian and international drinking water standards. In nearshore areas such as harbours, connecting channels and bays, concentrations may exceed GLWQA objectives.

2. Analyses of lake bottom sediments indicate that the peak inputs of synthetic organic chemicals and heavy metals to the lakes occurred in the 1960s and 1970s followed by declines in the 1980s. These declines reflect the increased regulation of the uses of organochlorine pesticides, PCBs and mercury in the early 1970s.

3. Levels of contaminants in Great Lakes fish and aquatic birds have decreased substantially from the high values reported in the 1970s. Since the early 1980s contaminant levels in wildlife have remained essentially constant. Contaminant levels in fish have not remained constant but have fluctuated around a lower level. Stabilized contaminant levels indicate continued chemical input to the Great Lakes basin.

4. The Great Lakes support the largest freshwater fishery in the world. Commercial fishery closures resulting from toxic contaminants first occurred in Lake St. Clair and Lake Erie in the early 1970s. Since then, a number of commercial fisheries have been closed in all of the Great Lakes. In the early 1980s some of the closed fisheries were reopened, most notably the walleye fishery in western Lake Erie and Lake St. Clair. Contaminant-related restrictions on harvest are still in place for many commercial fish species.

5. Fish consumption advisories have been issued in 36 of the 42 highly contaminated Areas of Concern. These advisories occur most frequently in long-lived top predators, such as lake trout, salmon and walleye, and for fish such as carp that inhabit contaminated nearshore environments. There are advisories for lake trout in all of the Great Lakes except Lake Erie. Lake trout consumption advisories are in effect at all sites tested in Lake Ontario. For lake trout the number of fish advisories issued in Lakes Ontario and Superior has not changed since 1983.

6. Multimedia analyses of national and Great Lakes regional data indicate that 80% to 90% of human exposure to persistent chlorinated organics comes from food, 5% to 10% from air and less than 1% from water. Municipal treated drinking water drawn from the Great Lakes contains minute quantities of organochlorines but the amounts rarely exceed current guidelines for Canadian drinking water quality.

7. The effects of contaminants on Great Lakes fish populations and fish communities are difficult to separate from the effects of overfishing, habitat loss and the introduction of exotic species. There is good circumstantial evidence that contaminants were involved in the mass mortality of developing lake trout embryos in Lake Michigan during the early 1980s.

8. There is convincing evidence from laboratory data that toxic chemicals ultimately affect the survival, growth and reproduction of some fish species in the Great Lakes. Many of the sublethal responses to chemical exposure, such as elevated enzyme activity, deformed fins and the occurrence of tumours, indicate that fish are metabolizing toxic substances. Bottom-dwelling species such as brown bullhead and white sucker are

closely associated with contaminated sediments and have been used to monitor the prevalence of tumours in fish throughout the Great Lakes. Both species exhibit liver and epidermal tumours. Epidermal tumours appear to be associated with non-chemical factors. However, the geographic distribution of liver tumours combined with laboratory studies strongly suggests that these tumours are caused by environmental chemicals.

9. Eleven wildlife species (two mammals, eight birds and one reptile) in the Great Lakes basin have experienced reproductive and other problems attributable to chemical contaminants. All are long-lived fish-eating species. In the last decade there have been significant recoveries in reproductive success and increases in population for most of the affected bird species. Serious problems are now confined to a few highly contaminated areas. For example reproductive problems and birth defects are still occurring in cormorants and in terns in Lakes Michigan and Huron and in snapping turtles in Hamilton Harbour, Lake Ontario. Despite improved reproductive success, several biological indicators — vitamin A levels, thyroid function, heme biosynthesis and activities of detoxifying enzymes — remain abnormal in herring gulls over considerable areas of the Great Lakes basin.

10. The population increases of two species, the cormorant and ring-billed gull, have been outside the range of variation normally recorded for vertebrate species. The populations are now 20- to 40-fold greater than any recorded historically. These unprecedented increases indicate that some fundamental alterations in the Great Lakes ecosystem have occurred.

11. Although there has been some improvement, the number of bald eagles on the lower Great Lakes is only a small fraction of what it used to be. Pairs nesting along the shores of Lakes Michigan and Huron continue to reproduce poorly and no nesting has occurred on Lake Ontario since 1951. Lack of suitable habitat may limit this species' recovery in some areas.

12. Birth defects in young fish-eating birds have been recorded in ten species in the Great Lakes basin. The prevalence of crossed bills in cormorant chicks in Green Bay is 22 to 87 times higher than normal. Although rates of occurrence have decreased, chicks of both cormorants and terns have been found with birth defects in Lake Ontario as recently as 1988. A higher percentage of snapping turtles from the shorelines of Lakes Ontario and Erie have considerably higher numbers of unhatched eggs and deformed embryos than those from inland populations.

13. Wildlife studies have shown that developmental and reproductive effects can occur in a wide range of species including birds, reptiles, fish and mammals exposed to mixtures of contaminants in the Great Lakes basin. While differences exist in behaviour and exposure between humans and wildlife, research findings suggest that studies of human populations should focus on these subtle health effects.

14. The limited number of published studies available indicates that rates of cancer incidence and mortality and adverse reproductive outcomes in the Great Lakes basin are no higher than would be expected in any highly industrialized area of the country. Some epidemiological studies do show an association between maternal consumption of contaminated fish and adverse effects in developing children. Clearly some subpopulations (nursing infants and heavy consumers of contaminated fish and wildlife) in the Great Lakes basin and elsewhere in Canada have higher exposure to contaminants and are at greater risk. Others such as the elderly, the fetus or those who are already ill are also at greater risk because they may be more sensitive to the effects of pollutants. These subpopulations have not yet been adequately studied.

15. The limited human tissue residue data available indicate that the general population residing in the Great Lakes basin is probably not exposed to higher levels of the most persistent pollutants than people residing elsewhere in North America. However, individuals consuming large amounts of contaminated fish and wildlife, especially native peoples and sportsmen, have greater exposure to several persistent pollutants. Elevated levels of contaminants in the Great Lakes basin

(and elsewhere) do pose a threat to health but the precise nature and extent of the threat is unclear. Residents of the basin consuming large quantities of contaminated fish and wildlife should be aware of these concerns and reduce their intake of sport fish and wildlife in accordance with current advisories.

16. If the overall contamination of the Great Lakes is to be significantly reduced further, it will be necessary to address such problems as the remobilization of toxic chemicals from contaminated bottom sediments into the food web, long range atmospheric transport of toxics to the lakes, the slow leaching of contaminants from hazardous waste sites, the transfer of contaminants by tributaries to the lakes and continued input from point sources not yet adequately controlled.

Preamble

This report is a summary of the current scientific knowledge of concentrations of toxic chemicals in the Great Lakes and the associated effects on the fish, wildlife and humans living in the basin.

During the past two and a half years, Environment Canada, the Department of Fisheries and Oceans and Health and Welfare Canada have worked together to compile information on the levels, trends and effects of persistent toxic chemicals in the Great Lakes basin. This has resulted in a two-volume technical report entitled "Toxic Chemicals in the Great Lakes and Associated Effects". Volume I documents levels of toxic chemicals in water, sediments, fish, wildlife and humans. Volume II reviews what is known about the effects of these contaminants on fish, wildlife and people and contains a synthesis which is a scientific consensus on the significance of the technical data in both volumes. The material presented in this synopsis has been drawn from these two volumes.

Much has been written, spoken and conveyed through images about the levels of toxic chemicals circulating throughout the biosphere. Less has been written on the effects these chemicals have on individual species. There are comparatively fewer studies examining human health effects that are accepted by scientists and health professionals as authoritative or complete.

Based on our knowledge of chemicals and their toxicology, a pattern is emerging that suggests that persistent chemicals in the environment have a significant effect on wildlife species. We still know very little about the effects of a person's lifetime exposure to toxic organic chemicals and metals. Despite some uncertainties, it is clear that toxic chemicals are a threat to the entire ecosystem. As a result, the principle of "virtual elimination" of persistent toxic substances from the lakes has been adopted in the Canada-U.S. Great Lakes Water Quality Agreement. The national governments of both countries, together with the province of Ontario, the eight Great Lakes states and the large municipalities, are moving towards this goal using the regulatory processes, pollution prevention strategies and public education. In the meantime, government programs continue to monitor the health of the ecosystem, assess the extent to which it is impaired by toxic chemicals and develop means to reduce the impact of exposures.

The terms contaminants, persistent toxic substances and toxic chemicals are used interchangeably throughout this report. A number of persistent toxic substances are metals but the majority are organic chemicals. The terms organochlorines, organochlorine pesticides and chlorinated organic chemicals are used in the text. A glossary at the end provides definitions of the technical terms used in this report.

FIGURE 1. The Great Lakes Basin

Note: The 42 Areas of Concern are identified.

1

Introduction

The Laurentian Great Lakes are collectively the largest body of freshwater on this planet. They contain the astounding volume of 22,000 cubic kilometres of water or 21% of the surface freshwater on earth. Outflows from the Great Lakes are relatively small in comparison to the total volume of water. On an annual basis, less than 1% of this immense volume flows into the St. Lawrence River.

The most recent census figures estimate that 8 million Canadians and 28 million Americans live within the drainage basin (Table 1). There are 28 cities with populations of more than 50,000 people and 13,400 manufacturing and industrial plants located within the basin. We use the lakes, tributaries and connecting channels for our water supplies, recreation, transportation of goods, industrial processes and disposal of chemical and biological wastes. The production and release of chemicals associated with high densities of population and industry in the Great Lakes basin led to widespread concern over the impact of human activity on the ecosystem and the implications of a contaminated ecosystem for health. More recently, the importance of atmospheric deposition of chemicals from outside the basin and contaminants in food have also been recognized as contributing significantly to human exposure.

TABLE 1
Population and Land Use in the Great Lakes Basin

	Superior	Michigan	Huron	Erie	Ontario
Population					
Canada (1986)	176,365	—	1,053,115	1,705,470	4,867,880
U.S. (1986)	487,100	12,051,200	1,408,000	10,827,300	2,507,400
Total	663,465	12,051,200	2,461,115	12,532,770	7,375,280
Basin Land Use (Percentage)					
Agricultural					
Canada	0.5	—	21	80	44
U.S.	6.0	44	40	63	33
Total	3.0	44	27	67	39
Shoreline Use (Percentage)					
Agricultural					
Canada	N/A	—	4	21	30
U.S.	N/A	20	15	14	33
Residential and Commercial					
Canada	N/A	—	69	49	43
U.S.	N/A	51	74	57	48
Recreational and Other					
Canada	N/A	—	27	30	27
U.S.	N/A	29	11	29	19

Sources: *The Great Lakes: An Environmental Atlas and Resource Book*, 1987.
Population data: Statistics Canada.

Historical Overview

The modern transformation of the Great Lakes basin ecosystem began with the arrival of European immigrants in the late 18th century. Initially, changes to the landscape and aquatic ecosystem were caused by settlements, forestry and agricultural practices. These were followed by bacteriological problems associated with urban sewage. Human activities in the 20th century have been responsible for a depletion of the fish populations from overfishing, a drastic restructuring of the shorelines from intensive waterfront activities and the excessive eutrophication of Lake Erie. As more synthetic chemicals were manufactured and used and more industrial and domestic wastes were generated, the lakes became increasingly used for the disposal of wastes. As a result, they became progressively more contaminated. For example:

- As early as 1963, studies of the herring gull in Lake Michigan revealed poor reproductive success and high levels of DDT/DDE.
- In 1968 high concentrations of mercury were found in the sediments of Lakes Ontario and Huron. At that time, industries using the chlor-alkali process were discharging mercury directly into rivers and lakes. In 1970 mercury was found in fish from Lake Huron, Lake St. Clair, western Lake Erie, eastern Lake Ontario and the St. Lawrence River, resulting in the closure of some commercial fisheries on the lakes.
- In 1971 a wildlife biologist visiting a colony of common terns in Hamilton Harbour observed eggs containing dead embryos and a young chick with a crossed-bill deformity. These problems were later linked to the presence of PCBs, DDT/DDE and hexachlorobenzene in the eggs.
- In 1971, as a result of finding PCB residues in fish, the Michigan Public Health Department issued the first advisory in the Great Lakes limiting the consumption of lake trout and salmon from Lake Michigan.
- In 1974 mirex was discovered in fish in the Bay of Quinte. The only known sources were a manufacturing plant on the Niagara River and another on Lake Ontario.
- In 1976 Ontario introduced the *Guide to Eating Ontario Sport Fish*. The 1990 edition provides consumption guidelines for fish caught by anglers from nearly 2000 locations on the Great Lakes and their connecting channels as well as inland lakes and rivers.
- In 1978 the Love Canal near Niagara Falls, New York, was declared a health emergency and 238 households were evacuated. A soup of industrial solvents, pesticides and process sludge long abandoned in an unused disposal canal had seeped its way into residents' backyards. One thousand and thirty households were eventually evacuated.

Critical Pollutants

In 1985, eleven of the most persistent and widespread toxic contaminants were identified as critical Great Lakes pollutants by the International Joint Commission (IJC). They are PCBs, DDT and its metabolites, dieldrin, toxaphene, dioxin (2,3,7,8-TCDD), furan (2,3,7,8 TCDF), mirex, hexachlorobenzene (HCB), mercury, alkylated lead, and benzo[a]pyrene (B[a]P). Eight of these critical pollutants are organochlorine compounds and are potentially harmful to life due to their chemical characteristics and their demonstrated toxicity. They are fat soluble and persistent in the environment and many have been used as pesticides or industrial chemicals. They are also found in industrial wastes, the combustion of wastes or fuels and as impurities in pesticides.

All of these eleven chemicals are widely distributed, tend to bioaccumulate in organisms, biomagnify in food webs, and despite some regulatory controls, persist at levels that exceed guidelines in some areas of the ecosystem. In 1985, nearly 1,000 compounds were identified in a chemical inventory conducted for the IJC. Three hundred and sixty-two chemicals were verified to have been measured at least once in the basin. Toxicity profiles have now been prepared for approximately 200 of these. Profiles are developed through a review of scientific literature covering acute, subchronic and chronic toxicity, carcinogenicity, mutagenicity and reproductive effects. Reproductive effects include teratogenicity (developmental toxicity), immuno- and neurotoxicity and behavioural effects.

Appendix I contains more information on each of the 11 critical pollutants.

Many of the chemicals found in the Great Lakes are classified as volatile organic compounds and tend to evaporate from lake water. These chemicals degrade fairly rapidly (non-persistent); however, they are widespread and some are highly toxic. Although this report focuses on persistent toxic substances, volatile organic chemicals are of concern.

- During the late 1970s, the word dioxin entered the lexicon as the name of the most toxic chemical found in the Great Lakes ecosystem.
- Today, public opinion polls have repeatedly indicated that Canadians are concerned about how exposure to toxic chemicals may be affecting their health. They would like to see strong governmental intervention to address their concerns.

Governments have acted to counter the progressive contamination of the Great Lakes. For example:

- In 1978 the Canada-U.S. Great Lakes Water Quality Agreement (GLWQA) was revised to address contamination by persistent toxic substances. The philosophy adopted for control of input of these chemicals to the Great Lakes was zero discharge.
- In 1976 federal legislation to control chemicals which pose a significant danger to human health and the environment came into force (Environmental Contaminants Act).
- In 1980, the use of PCBs in Canada was restricted to the existing electrical and mechanical equipment. The import or manufacture of any PCB-filled equipment was prohibited.
- In 1987 the GLWQA was amended. The governments of Canada and the United States, together with the province of Ontario and the eight Great Lakes states, committed to the cleanup of 42 severely polluted sites in the Great Lakes basin. (These Areas of Concern are shown in Figure 1.)
- In 1987 a declaration of intent was signed by the two countries to reduce the discharge of specific toxic chemicals in the Niagara River by at least 50% by 1996.
- In 1988 the Canadian Environmental Protection Act (CEPA) was proclaimed. It provides a framework to establish and apply controls to toxic substances throughout their life cycle.
- New regulations under CEPA to control dioxins and furans in pulp and paper mill discharge will require modifications to the chlorine bleaching process (used in ten Great Lakes mills). This reform will lead to the virtual elimination of dioxins and furans in the effluent by 1996.
- In 1990 Canada and the United States agreed to develop a Pollution Prevention Strategy for the Great Lakes. An agenda for action by all sectors of society to meet the goal of virtual elimination will be drawn up.

The Behaviour of Toxic Chemicals in the Ecosystem

The pathways and fate of toxic chemicals in lakes are governed by physical, chemical and biological laws. A molecule of a chemical present in the water can enter into chemical reactions that change its structure and increase or decrease its toxicity. It may be taken up by biota, be deposited in the sediments at the bottom of the lake, or be vaporized into the atmosphere. Industrial solvents found in the water tend to evaporate and may degrade in the atmosphere or be re-precipitated. There is evidence that chlorinated organic chemicals deposited in the past are "evaporating" from the lakes. This mechanism contributes to the detoxification of the lakes but also enables these chemicals to be redistributed globally. In the shipping channels and in the shallow lakes and bays such as Lakes Erie and St. Clair, Saginaw Bay and the Bay of Quinte, sediments can be disturbed and the resuspended materials, including toxic chemicals, may enter biological systems. A proportion of the toxic chemicals in the water and sediments, whether they are dissolved or insoluble, will inevitably enter the aquatic food web.

A substance is bioaccumulated when it is concentrated in an organism faster than it is being excreted. Predatory organisms effectively biomagnify the concentration in their own bodies by eating large numbers of contaminated prey. For example, fish-eating aquatic birds, such as herring gulls, are found to have higher concentrations in their bodies than the fish they eat.

Removal of toxic chemicals also takes place in lakes by chemical and biological processes. Living systems in the lakes rely on the primary productivity of plankton. Under enriched nutrient conditions, more plankton are produced and toxic substances which move into the food web will remain in the lower trophic levels or be buried by sedimentation. The excess plankton in effect divert chemicals from the higher trophic levels. This can be seen in Lake Erie where fish and birds have markedly lower tissue burdens of some persistent toxic chemicals.

Nature of the Problem

Environmentally persistent toxic substances enter the lakes via direct industrial discharge pipes, effluent flow from municipal sewage treatment plants and storm sewers. These are often referred to as point sources and are subject to varying degrees of government regulation. The level of treatment applied depends on the industrial sector, the city and the regulations in effect. The amounts can be enormous. For example, the city of Detroit discharges about 3.2 billion litres of wastewater (700 million gallons) every day into the Detroit River and about 73 kilograms of PCBs annually.

Toxic chemicals enter the Great Lakes by a number of other pathways, of which air deposition is one example. Chemicals present in the Great Lakes basin may have been transported through the atmosphere from thousands of miles away. Consequently, they are difficult to regulate in target areas. The large surface areas of Lakes Superior, Huron and Michigan mean that they each receive a large percentage of their contaminant load from the atmosphere (see Table 2).

Another important pathway is the run-off of organochlorine pesticides from farm land into streams and subsequently into the lakes. Contamination of this type is often referred to as non-point source pollution. In the 1960s and 1970s restrictions were placed on the use of the pesticides DDT, hexachlorobenzene and dieldrin.

A fourth source is the chemical waste stored in large quantities by industries and by municipalities in waste and landfill sites. Over time these underground storage facilities have seeped unknown quantities of hazardous chemicals into the water table. Leachate from sites along the Niagara frontier continues to migrate through the groundwater and into the Niagara River. An estimated 315 kilograms per day of toxic chemicals currently enter the river from the largest U.S. hazardous waste sites that are within three miles of the river.

With current analytical techniques, scientists are able to detect the concentration of some chemicals in water at the parts per quadrillion level. (By comparison, sensitive noses can detect the odour of fuel oil at one part per billion. A part per billion is a billion times greater than a part per quadrillion.) The International Joint Commission (IJC) has developed a working list of 362 chemicals considered to be unequivocally present in water of the Great Lakes. These measurements indicate that a compound has entered the lake ecosystem but do not reveal the source of the chemical or its eventual fate. By analyzing sediment cores taken from the lake bottoms, scientists have been able to reconstruct events. Serious chemical contamination of the Great Lakes began after World War II and continued to increase until the 1970s. The continued presence of persistent toxic chemicals in the ecosystem is confirmed by concentrations measured in lake bottom sediments and the tissue burdens of fish, birds and humans. (See box, page 5.)

TABLE 2
Chemical Loads[1] to the Great Lakes and Percentage Attributable to Atmospheric Deposition

	LAKE BASIN									
	Superior		Michigan		Huron		Erie		Ontario	
	kg/yr	%	kg/yr	%	kg/yr	%	kg/yr	%	kg/yr	%
PCBs	606	90	685	58	636	63	2520	7	2540	6
DDT	92	97	65	98	92	97	319	22	111	32
Benzo(a)pyrene	72	96	208	86	290	80	122	79	155	72
Lead	241	97	543	99	430	94	567	39	426	50

1. Data to carry out mass balance were sufficient only for these four chemicals and mirex; even for these there is a great deal of uncertainty.

Note: The upper lakes, Superior, Michigan and Huron, receive a significant fraction of their PCBs, DDT and lead directly from the atmosphere. Compared to the lower lakes, they have larger surface areas and fewer local contaminant sources. In absolute terms, total PCB inputs to the lower lakes are four times higher than to the upper lakes due to local sources.

Source: *Mass Balancing of Toxic Chemicals in the Great Lakes,* International Joint Commission 1988.

Hydrological Features

The five Great Lakes are linked by four connecting channels and are drained by the St. Lawrence River. The lakes and channels possess unique attributes that influence the behaviour of toxic chemicals that enter their waters. Table 3 shows that the water retention time varies considerably between lakes. A molecule of water entering Lake Superior in 1960 could remain there well into the 22nd century. On the other hand, water is flushed out of Lakes Erie and Ontario very rapidly through the Niagara and St. Lawrence rivers. The connecting channels move water and sediments rapidly downstream; the wastes from the high concentration of industry along the St. Clair, Detroit and Niagara rivers are loaded into the lower lakes.

TABLE 3
Hydrological Features of the Great Lakes and Connecting Channels

	Superior	Michigan	Huron	Erie	Ontario
Maximum Depth (m)	405	281	229	64	244
Lake Surface Area (km^2)	82,100	57,800	59,600	25,700	18,960
Land Drainage Area (km^2)	127,700	118,000	134,100	78,000	64,030
Total (km^2)	209,800	175,800	193,700	103,700	82,990
Volume (km^3)	12,230	4,920	3,540	480	1,640
Residence Time[1] (years)	191	99	22	2.6	6

	St. Marys River	St. Clair River	Lake St. Clair	Detroit River	Niagara River	St. Lawrence River
Length (kilometres)	101-121	64	1115 km^2 (area)	51	59	240
Average Flow (m^3/sec.)	2,200	5,200	—	5,300	5,800	7,200
Flushing Time[2]	2 days	21 hrs.	2-9 days	21 hrs.	n/c	n/c
Time of Travel of Surface Water (hours)	<24	6	—	5	16	240

n/c = not calculated

1. The residence time of water in a lake is the time that it would take to replace all of the water if it were all flushed through the outlet.
2. Flushing time of water in a river is the time taken to replace all of the water.

Note: The residence time of any particular toxic chemical in a lake is shorter than for water due to factors such as burial in bottom sediments, evaporation and whether the chemical is biodegradable.

Source: Environment Canada.

2

Contaminants in Water and Sediments

Water

In recent years, sensitive analytical techniques have been developed to measure very low concentrations of contaminants. Until 1980 there were few reliable data on concentrations of toxic metals and organic chemicals in Great Lakes water. Improvements now permit the reliable detection of metals, pesticides and industrial organic chemicals in parts per trillion and in some cases parts per quadrillion.

Synthetic chemicals in the open waters of the Great Lakes occur in the parts per trillion range or lower. The open water is generally less polluted than the nearshore water. In the nearshore areas, harbours, stream mouths, embayments and the connecting channels, water quality guidelines for specific chemicals are often exceeded. The guidelines themselves are set in the parts per billion range or lower (Table 4).

Based on an overall appraisal of toxic chemical concentration in water, suspended sediments and bottom sediments, Lakes Ontario, Michigan and Erie have the highest concentrations of toxic and persistent chemicals. Lakes Superior and Huron are the least contaminated, with the exception of some local areas. Concentrations of chemicals in the open waters of the lakes are below Great Lakes Water Quality Agreement specific objectives.

To detect the presence of toxic organic chemicals, large volumes of water are collected; however, this procedure is costly and time consuming. Recent programs have focused attention on detecting chemicals in the 42 Areas of Concern including the international connecting channels (the Niagara, Detroit, St. Clair and St. Marys rivers) where there are known sources of priority chemicals.

Earlier measurements of toxic metals (lead, mercury, cadmium and arsenic) in water were likely distorted by the presence of these ubiquitous metals as dust in sampling equipment and in the laboratory. True water concentrations in the 1960s and 1970s were likely far lower than previously thought. Special laboratory procedures have since corrected this problem. Scientists have difficulty in comparing historic with recent data; statements about long-term trends for metal concentrations in water, therefore, are questionable. Present concentrations of metals dissolved in water are in the parts per trillion range.

The detection and measurement of extremely low concentrations of toxic chemicals in the water may help scientists to relate the presence of a contaminant in samples of water to the higher levels found in plankton, fish and wildlife. Unfortunately, there is probably no simple relationship between the concentration of a chemical in water or the sediments and that found in aquatic organisms. Environment Canada and other agencies measure chemicals in water to assess whether water quality guidelines are being met. For diagnostic purposes these ambient water quality measurements are imprecise. The concentrations in the connecting channels and nearshore can vary considerably with the rapid movement of water, seasonal variations, and resuspension of sediments following storms. These variations in natural conditions make it difficult to establish time trends for water concentrations with any certainty. Biological communities which act as long-term integrators of these fluxes provide data showing that contaminant levels in Great Lakes fish and birds have decreased. Over the past 15 years, industrial and agricultural loadings have been regulated to some extent, thus it is reasonable to assume that concentrations in water have also decreased.

Sediments

Sediments in lakes and rivers are composed of inorganic (mineral) and organic matter. Due to their physico-chemical properties, PCBs and the organochlorine

TABLE 4
Persistent Toxic Substances in the Great Lakes

Substance	Water Quality Objective[1] (parts per billion)
Persistent Organic Chemicals[2]	
Aldrin/dieldrin	0.001
Benzo[a]pyrene	0.01
Chlordane	0.06
DDT (total)	0.003
Endrin	0.002
Heptachlor (total)	0.001
Lindane	0.01
Methoxychlor	0.04
Mirex	0.005[4]
PCP (pentachlorophenol)	0.4
DEHP (Di-2-ethylhexylphthalate)	0.6
PCBs (polychlorinated biphenyls)	0.001 (proposed)
Toxaphene	0.008
2,3,7,8-TCDD (a dioxin congener)	0.00001 (detection limit)
Metals	
Arsenic	50
Cadmium	0.2
Chromium	50
Copper	5
Lead[3]	10.0 – 25.0
Mercury	0.2
Selenium	10
Zinc	30

1. As stated in the 1978 Great Lakes Quality Agreement or subsequently proposed. Levels are set to protect the most sensitive user (not always humans).
2. For persistent, toxic organic contaminants for which objectives have not been defined, the concentrations of such compounds in water or aquatic organisms should be less than detection levels as determined by the best scientific methodology available. No guidelines have been established for OCS (octachlorostyrene), HCB (hexachlorobenzene), BHC (benzene hexachloride), TCDF (tetrachlorodibenzofuran) and HCBD (hexachlorobutadiene).
3. Concentration depends on the lake. Lower objectives were set for Lakes Superior and Huron.
4. Objective for mirex is "substantially absent" or below the level of detection as determined by the best methodology (presently 0.005 ppb).

Note: Objectives for fish are discussed in chapter 3.

pesticides and metals adsorb to the suspended particulate sediment phase in water. The suspended sediments are also partially composed of plankton which can bioaccumulate metals and toxic organic chemicals. As a result, suspended sediment concentrations of PCBs can be 1000 times higher than in water. Eventually, suspended sediments are either propelled downstream or are deposited on the lake bottom in depositional or sedimentary basins. For example, the surficial layers of the sediments of Lake St. Clair have elevated mercury concentrations as a result of loading from the St. Clair River.

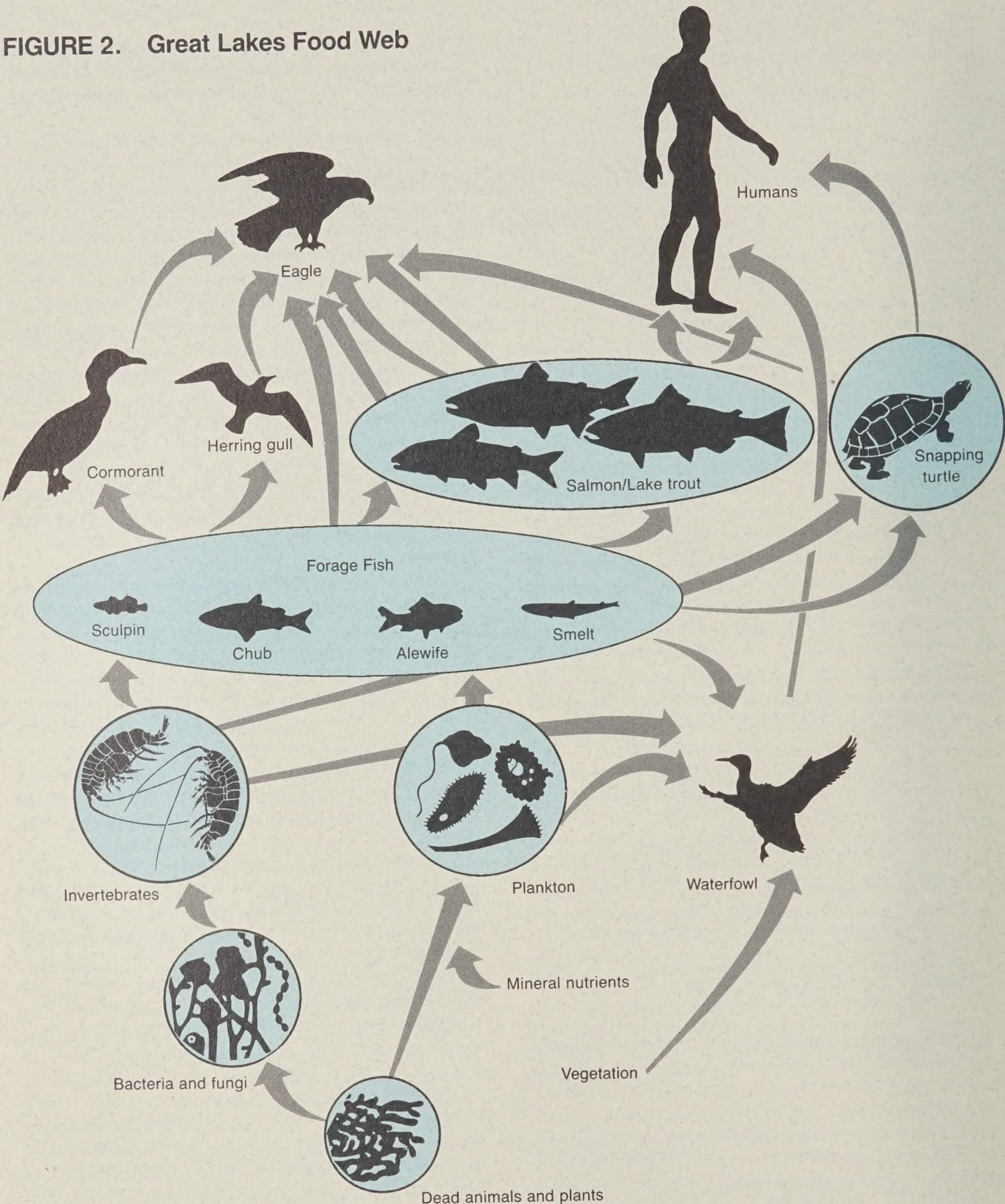
The collection of sediment cores from the bottom of the lakes is a useful method of determining historical trends of chemical inputs to the lakes. Sections of these cores are analyzed in relation to depth, and this gives a profile of deposition over time. Through radioactive dating of the sediment core material, scientists can record pre-industrial levels of a synthetic chemical (zero) or a metal, track its increases and decreases over the past 40 years and determine the changes resulting from regulations or discontinued use.

The historical trends for most contaminants indicate that the loadings of nearly all persistent toxic chemicals peaked in the 1960s and 1970s. These peak inputs were followed by decreases reflecting control actions for organochlorine pesticides, PCBs, lead and mercury. Even so, in the Niagara, Detroit and St. Clair rivers, levels of mercury in bottom sediments remain above guideline levels for the disposal of dredged material.

Sediment cores taken from Lakes Huron and Erie show that dioxins and furans continue to be deposited to the sediments at the same rate as in the 1960s, although there has been a slight decline in Lake Erie since the mid-1970s. Continued atmospheric inputs of these combustion by-products are likely the reason. Lead in sediment cores in Lakes Superior and Michigan are at 1970 levels or slightly below. As controls on automobile emissions become more stringent and gasoline containing lead is phased out in Canada (1991), the rate of lead deposition should begin to decline again.

The pesticide mirex was manufactured in a plant situated on the Niagara River from the 1950s until 1976, and the record of the sediment cores taken from the delta area of the river in 1980 tracks this industrial activity. But in 1981, analysis of sedimentary basins on the south shore of Lake Ontario showed that deposition of this chemical was still occurring. Remobilization of contaminated Niagara River sediments is suspected. Sediment core records of the deposition of PCBs in the Niagara River delta show that the highest concentrations correspond to the early 1960s. Levels have now plateaued at levels equivalent to those for the 1950s. As with mirex, PCBs have been flushed into Lake Ontario from the Niagara River. Mapping of Lake Ontario bottom sediments show a PCB plume extending out from the mouth of the Niagara River.

FIGURE 2. Great Lakes Food Web



NOTE: This is a simplified representation of the food web showing the main pathways. Food (energy) moves in the direction of the arrows. The driving force is sunlight. Depictions of the various organisms are not to scale.

3

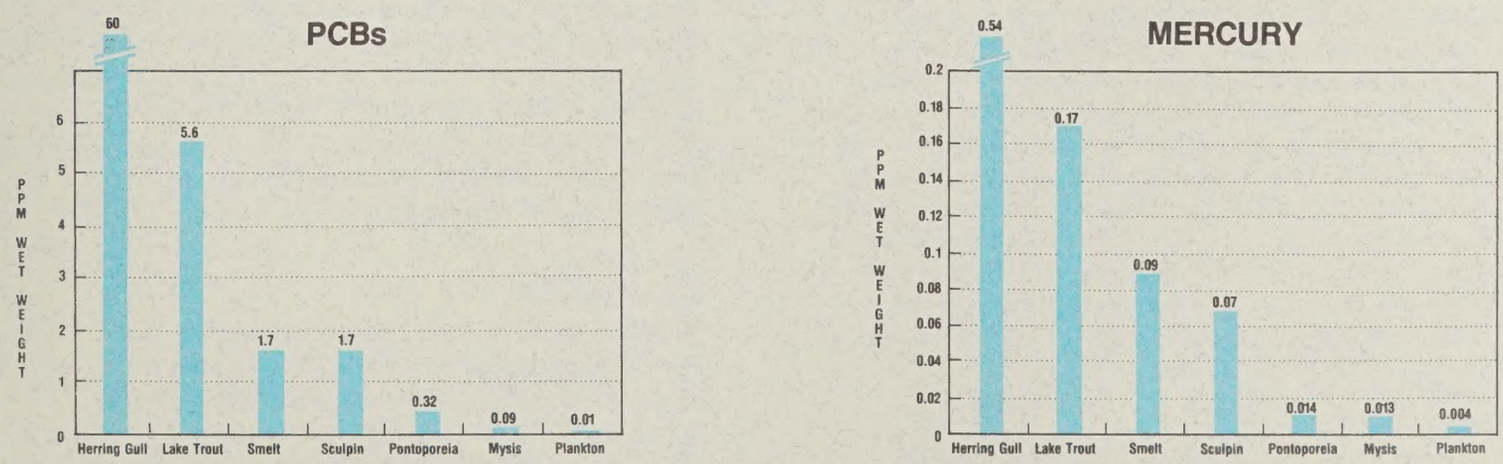
Toxic Contaminants: Levels and Effects in the Great Lakes Food Web

All species have evolved the ability to selectively absorb essential chemical elements and natural compounds from their environment. The physical and chemical properties of heavy metals and many synthetic chemicals allow them to gain entry into organisms, resist being metabolized or excreted, and thus bioaccumulate. If the organism continues to be exposed to chemicals in its environment that it cannot adequately excrete or detoxify, concentrations can increase to toxic levels. Some of the critical pollutants can cause carcinogenic, reproductive and developmental effects even at relatively low concentrations. In the Great Lakes, the levels of contaminants found in fish and wildlife species depend on a variety of factors including habitat, body size, selection of prey, energy requirements, position in the food web, ability to metabolize contaminants and, in the case of organochlorine chemicals, fat levels in tissues.

The biomagnification of chemicals such as PCBs, dioxins and organochlorine pesticides from the lowest trophic levels (phytoplankton) through to top predators (fish-eating birds and humans) has been observed in the Great Lakes food web (Figure 2). Since organochlorines are much more soluble in fat than in water, they are absorbed from the water by phytoplankton (microscopic plants and algae) into their fats. These small organisms are eaten by larger ones, passing the contaminants up the food web to fish and eventually to the aquatic birds and mammals. Since many smaller organisms are eaten by a single predator, the total amount of contaminant ingested is higher than in its prey. Taken together with the fact that aquatic animals excrete organochlorine chemicals very slowly (or not at all), these contaminants build up to higher concentrations at each step in the food web (Figure 3).

In another pathway, contaminants are absorbed from the sediments by bottom-dwelling animals such as tubificid worms, insect larvae, molluscs or crayfish and accumulate in ducks, turtles and bottom-feeding fish such as white suckers, brown bullheads and carp.

FIGURE 3. Biomagnification of PCBs and Mercury in the Lake Ontario Food Web, 1982



Source: Environment Canada and Department of Fisheries and Oceans

Note: The pathway from plankton through to herring gull was selected from the food web.
The year 1982 was used since this was the most recent year when plankton, *Mysis* and *Pontoporeia* data were available. The concentration of PCBs in the open waters of Lake Ontario was measured at 5 ppt in 1986; thus, there is a bioconcentration factor of 10 million from water to herring gull eggs.

In addition, fish also absorb toxic chemicals directly from the large amount of water flowing across their gills as part of their normal respiration.

Ascending the food web, the factors of biomagnification become quite large. For example, PCBs in Great Lakes water are present in concentrations in the low parts per trillion range; PCBs in the eggs of eagles at the top of the Lake Erie food web have been measured at greater than 25 parts per million as recently as 1988. This corresponds to a biomagnification factor of 25 million. Biomagnification factors for mercury and PAHs are less spectacular (usually 1000).

Contaminant Residues

Regulatory actions implemented by governments in the 1970s to restrict the use of organochlorine pesticides and PCBs have led to substantial decreases in contaminant concentrations in Great Lakes fish and wildlife. Data sets for PCBs, DDT, mirex and hexachlorobenzene in lake trout and herring gulls illustrate this trend. Contaminant levels in fish and fish-eating birds have now reached a plateau. This is because some of the chemicals are extremely persistent and some inputs have yet to be controlled.

Fish

Concentration levels of contaminants in fish are influenced by position in the food web, portion of the fish analyzed and the age and fat content of the individual. In order to standardize these factors, and thus be able to make comparisons between lakes and discern time trends, top predator species are collected, chemical analyses are made using whole fish and data

Biomonitoring

Birds

By the early 1960s, it was evident that the bald eagle and other birds were suffering reproductive problems linked to exposure to the pesticide DDT and other industrial chemicals. In the late 1960s field biologists began observing declines in the populations of fish-eating birds in the Great Lakes basin. Scientists studying populations of these species from Lakes Ontario and Michigan found that they were among the most contaminated in the world. In 1974 the Canadian Wildlife Service established a monitoring program to measure organochlorine contaminant residues in herring gull eggs at 13 colonies throughout the Great Lakes basin on an annual basis.

Fish-eating birds and predatory fish are at the top of the Great Lakes food web and measurements of their tissue burdens serve as indicators of ecosystem contamination. The herring gull was chosen as a Great Lakes biomonitor in 1974 since gull populations were not as severely affected as cormorants and terns, and gulls continued to lay eggs. Herring gulls are found throughout the basin, they remain year-round and their diet is mainly fish. Bird eggs were chosen as monitors because this is the least disruptive way of measuring levels in the food web. Females will replace eggs lost early in the season and no adults need to be killed in order to measure pollution levels. Within each lake, herring gulls remain in the vicinity of their colony for much of the year and thus function as an integrator of contaminants on a regional basis.

Fish

There are four programs involving Canadian agencies which monitor fish contaminant levels in the Great Lakes.

(1) The Open Lake Fish Contaminant Program is conducted jointly by the Department of Fisheries and Oceans and the U.S. Environmental Protection Agency and the U.S. Fish and Wildlife Service. Since 1977, the program annually measures concentrations of persistent toxic chemicals in top predator fish (lake trout and walleye) and forage fish (rainbow smelt and bloater chub). Since contaminants accumulated by fish concentrate in all tissues, the program analyzes whole fish.

(2) The Ontario Ministry of the Environment (MOE) collects young-of-the-year spottail shiners from the connecting channels and tributary mouth locations on the Great Lakes. As shiners (a minnow) are non-migratory, and only young-of-the-year are selected, this reflects local contaminant levels and indicates recent loadings.

(3) Sport fish are collected by the Ontario MOE and the Ministry of Natural Resources (MNR) and the lean, dorsal muscle tissue is analyzed. The *Guide to Eating Ontario Sport Fish* gives results on an annual basis.

(4) The Department of Fisheries and Oceans collects and analyzes fish fillets prepared for sale by commercial fishermen in the Great Lakes.

Other Species

Net plankton, *Mysis* (a large zooplankton) and *Pontoporeia* (bottom dwellers) were selected as biomonitors under the Great Lakes Water Quality Agreement. These organisms were selected to quantify pollution gradients as they bioaccumulate residues and to predict food chain biomagnification since they compose major diet items of fish.

are reported for specific age classes. The lake trout serves as the top predator species for Lakes Ontario, Huron, Michigan and Superior, and the walleye is used for Lake Erie.

Lake-wide Trends

Fish from Lakes Ontario and Michigan generally have higher contaminant burdens than those from the other lakes based on the most recent data sets (1988) for organochlorine pesticides, PCBs and dioxin. Among the Canadian Great Lakes, lake trout from Lake Ontario have the highest levels of PCBs, DDT, mirex, dieldrin and dioxins, while lake trout from Lake Superior have the highest toxaphene levels. Lake St. Clair walleye have the highest mercury levels. Annual data show that since the late 1970s, the largest declines have occurred in Lakes Ontario and Michigan, while the most consistent decrease across the range of chemicals has occurred in fish from Lake Erie. This lake has the shortest residence time of the five large lakes and it is thought that contaminants adsorbed to particles are effectively flushed from the lake and down the Niagara River. It also has the most biomass and thus the amount of contaminant in an individual is proportionately less.

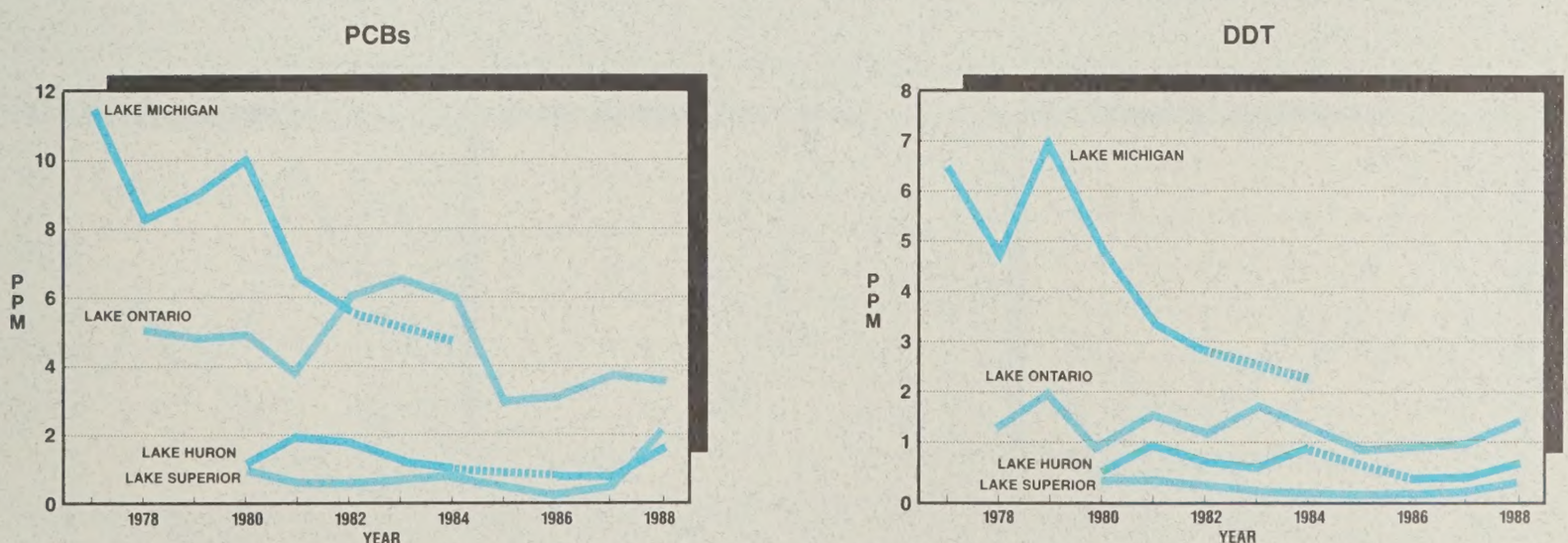
Since the 1970s, levels of PCBs and DDT in lake trout have shown a declining trend followed by a levelling off in Lakes Ontario and Michigan with the most dramatic drop occurring in Lake Michigan (Figure 4). There do not appear to be consistent trends for these compounds in lake trout from Lakes Superior and Huron. Atmospheric deposition to these two lakes is likely responsible.

Great Lakes Water Quality Agreement Specific Objectives

Under the Canada-U.S. Great Lakes Water Quality Agreement (GLWQA), specific objectives have been set for a number of persistent toxic substances in water and whole fish to protect the health of humans and fish-eating birds and to maintain the integrity of the ecosystem. There are objectives for all organochlorines discussed in this report except dioxins, furans, hexachlorobenzene and octachlorostyrene.

The most recent data for lake trout indicate that concentrations of PCBs in whole fish remain above the GLWQA objective of 0.1 ppm in all of the Great Lakes and connecting channels including the St. Lawrence River. DDT/DDE levels in lake trout are below the objective of 1 ppm in all lakes except Ontario and Michigan. The GLWQA objective for mirex is "substantially absent" in water or fish but it continues to be detected in spottail shiners, lake trout and rainbow smelt from Lake Ontario. Mirex residues were also detected in spottail shiners collected in the early 1980s from the Niagara and St. Lawrence rivers. Mercury concentrations in Lake St. Clair walleye have recently dropped below the objective of 0.5 ppm; how-

FIGURE 4. Concentrations of Contaminants in Lake Trout from the Great Lakes, 1977–1988



Note: These are the average annual concentrations in parts per million wet weight of total PCBs and DDT in whole lake trout. Fish from the Canadian lakes are 4 years of age; fish from Lake Michigan are between 620 and 640 mm in length.
The pesticide DDT is metabolized by biological systems to several other compounds. Total DDT refers to the complex of DDT and its metabolites.

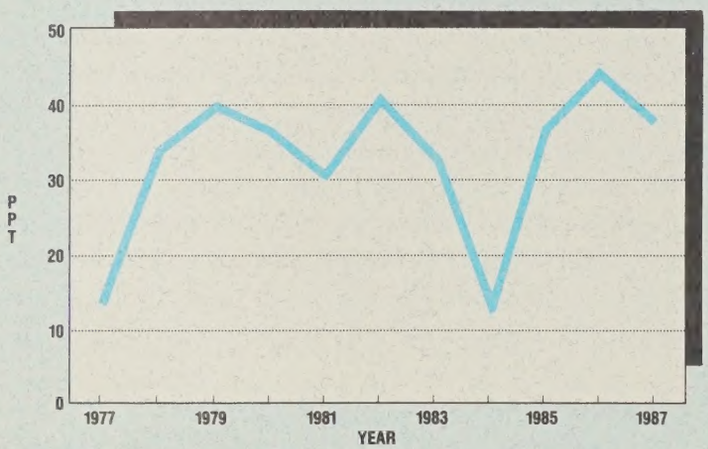
Source: Department of Fisheries and Oceans and the U.S. Environmental Protection Agency.

Lake Ontario Case Study

Lake Ontario is situated "downstream" from the other Great Lakes and the connecting channels. It is subject to several chronic sources of contamination. As a result, there has been little recent change in the residue levels (PCBs, DDE, dioxin, dieldrin, hexachlorobenzene, mirex) found in lake trout and herring gull eggs. The largest single source of persistent toxic chemicals to the lake is the Niagara River drainage basin where an estimated 1.2 million tons of contaminated material have been stored in the 66 largest waste sites over the past 50 years. These sites are leaching or have the potential to leach toxic chemicals into the fast-flowing river and to be transported downstream to Lake Ontario. The Niagara River is the principal source of dioxin found in Lake Ontario fish. There are no obvious trends of dioxin in lake trout (Figure 5). The high dioxin levels in eggs from Lake Ontario gull colonies (Figure 6) are attributable to a chemical plant on the Niagara River that used to manufacture trichlorophenol for the production of pesticides. Dioxin (2,3,7,8-TCDD) can be formed in the production of this chemical and the wastewater could have entered the Niagara River and subsequently Lake Ontario. Production of the pesticide was discontinued in the mid-1970s and levels recorded in eggs from the Scotch Bonnet Island colony dropped. Residues measured in the 1980s show that levels in Lake Ontario colonies remain substantially higher than in the other lakes. A similar phenomenon has occurred in Saginaw Bay, Lake Huron, where the same chemical was manufactured nearby.

Contaminated bottom sediments are another ongoing source. Although mirex has not been manufactured

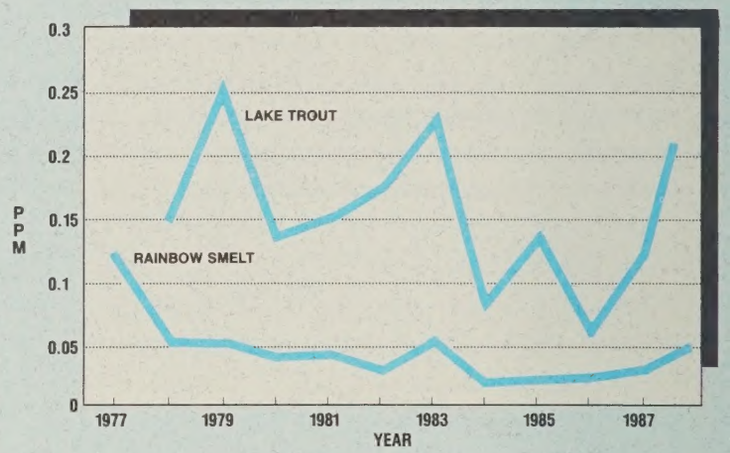
FIGURE 5. Dioxin Concentrations in Lake Trout from Lake Ontario, 1977–1988 (2,3,7,8-TCDD)



Average concentrations of the most toxic dioxin congener (2,3,7,8-TCDD) measured in parts per trillion wet weight in whole lake trout.

Source: Department of Fisheries and Oceans.

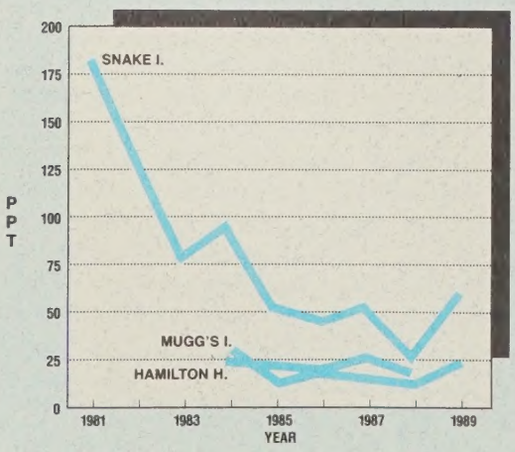
FIGURE 7. Mirex Concentrations in Lake Ontario Fish, 1977–1988



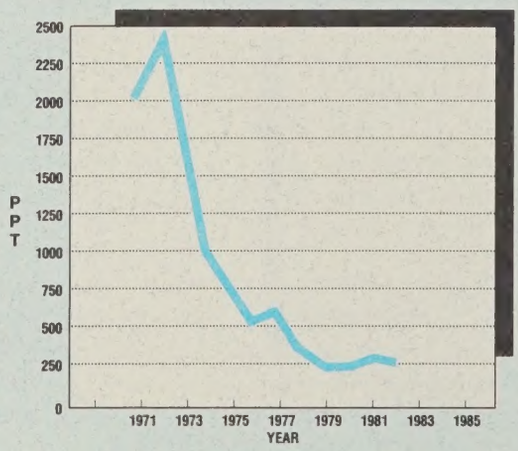
Average concentrations of the insecticide mirex measured in parts per million wet weight in whole fish.

Source: Department of Fisheries and Oceans.

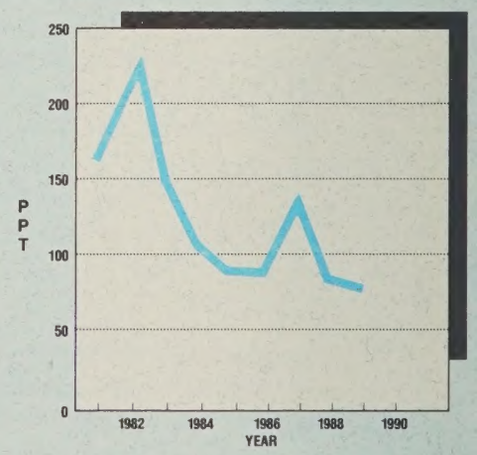
FIGURE 6. Dioxin (2,3,7,8-TCDD) Concentrations in Herring Gull Eggs



HAMILTON H., MUGG'S I., SNAKE I.



SCOTCH BONNET ISLAND



CHANNEL/SHELTER ISLAND
(Saginaw Bay)

Measured in parts per trillion wet weight.

Scotch Bonnet and Snake Islands are at the eastern end of Lake Ontario, Mugg's Island is at Toronto.

Source: Canadian Wildlife Service, Environment Canada.

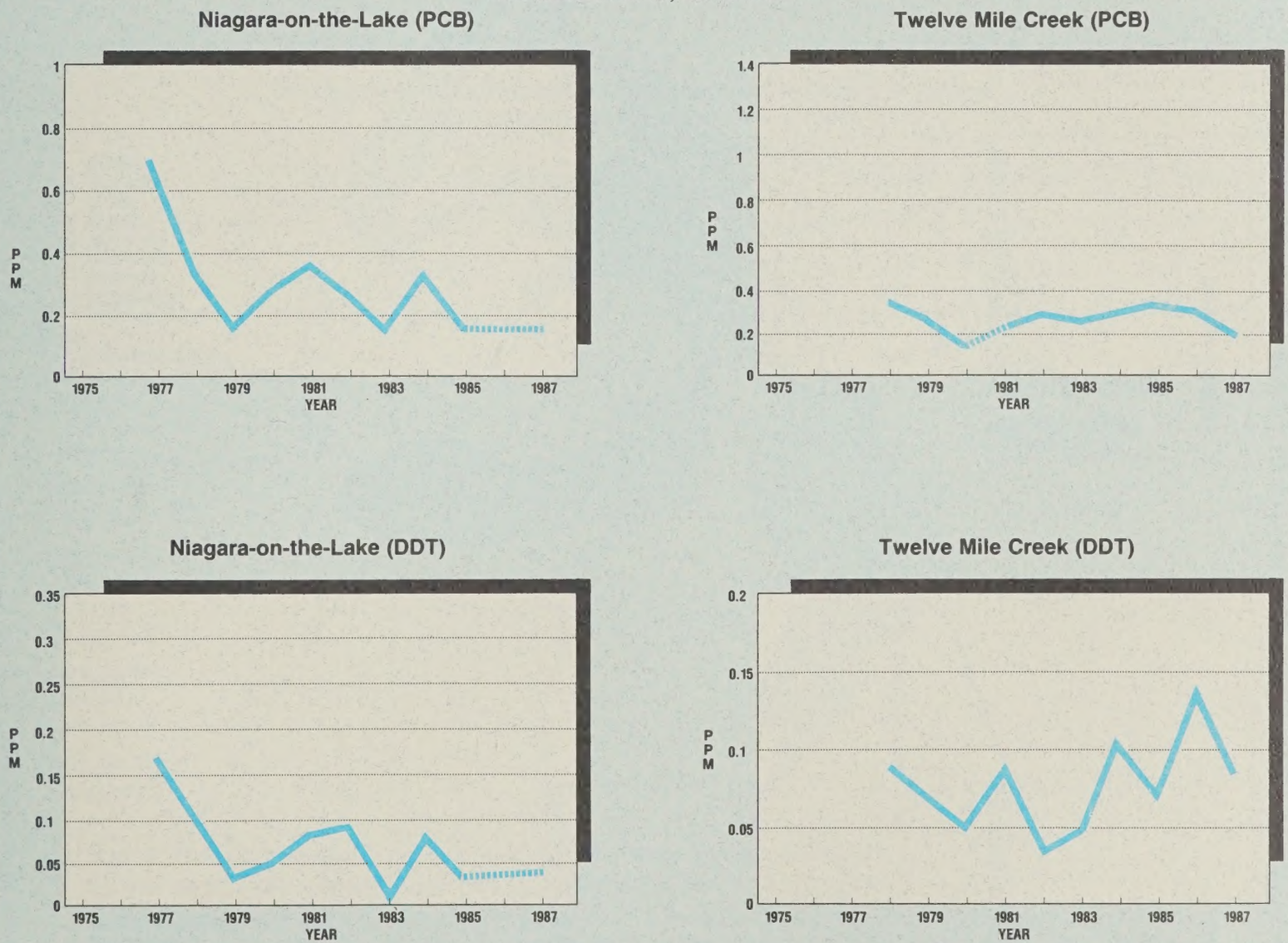
since 1976, it is still entering the food web through the resuspension of sediments. Levels of mirex in Lake Ontario fish, although lower today than during the late 1970s, are maintained almost entirely by the sediment pathway (Figure 7). Lake Ontario herring gull eggs also have the highest mirex levels compared to the other lakes by a factor of 10. Sediment resuspension also maintains the levels of other organochlorine pesticides in the Lake Ontario food web, even though their manufacture and use were restricted or banned in the 1970s.

Atmospheric deposition contributes to the contaminant burdens of fish. For example, pesticides applied to crops by aerial spraying can remain airborne for a number of days. Toxaphene, an organochlorine pesticide which was used very little in Canada after 1970 and was last used in Ontario in 1980, is still present in lake trout. This is because it is atmospherically transported from the southern United States, where it was applied in large amounts to cotton crops. Although data for this chemical are limited, levels have decreased since the U.S. manufacture of this chemical was banned in 1982.

It is suspected that chemicals previously applied to crops may still be present in agricultural soils. Volatilization from soils is another pathway through which chemicals can be mobilized in the ecosystem.

Finally, present day urban, rural and industrial effluents contribute PCBs, organochlorine pesticides and toxic metals to the lake. Measurements in young-of-the-year spottail shiners provide an indication of the distribution of these sources on the Canadian side of the lake. A number of examples are given in Figure 8.

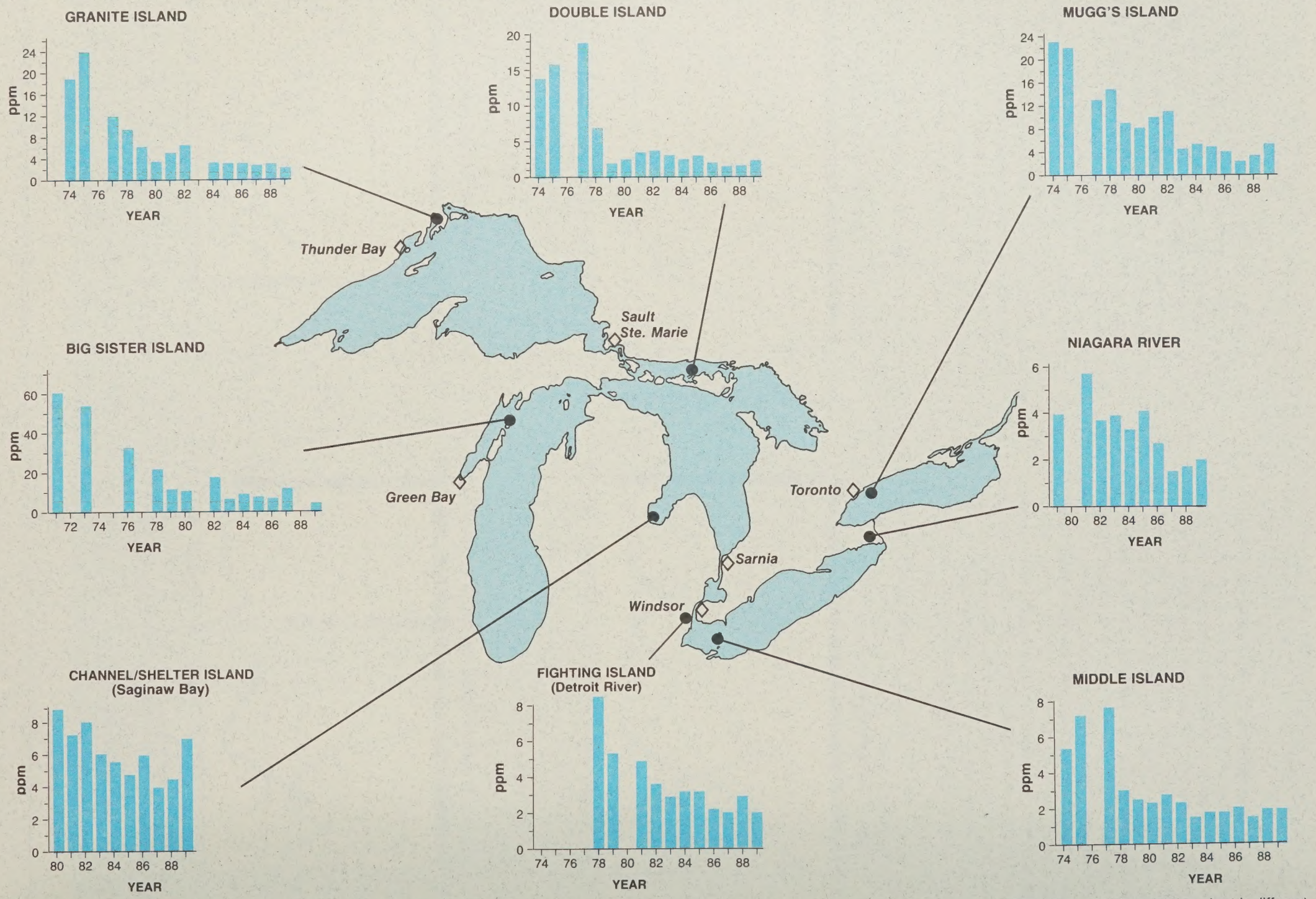
FIGURE 8. PCB and DDT Residues in Spottail Shiners Collected from Locations on Lake Ontario, 1975–1987



Average PCB and DDT residues measured in parts per million wet weight in Lake Ontario young-of-the-year spottail shiners collected at Niagara-on-the-Lake and Twelve Mile Creek.

Source: Ontario Ministry of the Environment.

FIGURE 9. Trends in DDE Concentrations in Great Lakes Herring Gull Eggs



Source: Canadian Wildlife Service, Environment Canada.

Note: The scale for each bar chart is different.

ever, levels in St. Lawrence River walleye collected from Lake St. Francis remain above the objective.

On a lake-wide basis, concentrations of persistent toxic substances in lake trout from Lakes Erie, Huron and Superior meet GLWQA objectives (for all compounds for which there are objectives) except PCBs.

Wildlife

A number of species of birds, including the bald eagle, osprey and most colonial nesting birds, aquatic mammals and turtles in the Great Lakes ecosystem rely on fish as their primary source of food. Through the process of bioaccumulation and biomagnification, these long-lived top predators have the highest levels of organochlorine chemicals in their tissues.

Herring Gull

The herring gull was selected as the principal wildlife indicator species for levels of contaminants in the Great Lakes ecosystem.

Since 1974 herring gull eggs have been collected from colonies and analyzed for residues of organochlorine compounds every year. It is likely that the highest levels of organochlorine contamination occurred in Great Lakes aquatic birds before this program began. With the exception of the pesticide dieldrin, organochlorine residues in herring gull eggs decreased from 1974 to the early 1980s. Since then, levels have remained essentially constant. These trends are in parallel with the lake trout. This is not surprising since they both eat smelt and alewife. Figure 9 shows this phenomenon for DDE at eight herring gull colonies on the Great Lakes.

TABLE 5
Organochlorine Contaminant Concentrations in Herring Gull Eggs[1] from Colonies on the Great Lakes, 1989

	CONTAMINANT[2]						
	PCB congeners[3]	DDE	MIREX	HCB	DIELDRIN	DIOXIN	%LIPID[4]
Lake Ontario							
Snake I.	14	5.2	1.1	0.07	0.14	91	8.6
Mugg's I.	16	5.3	1.2	0.06	0.12	55	8.6
Niagara River							
Island Above Falls	9	2.1	0.24	0.04	0.13	18	8.4
Lake Erie							
Port Colborne	17	3.1	0.33	0.05	0.23	19	10
Middle I.	21	2.3	0.03	0.05	0.11	16	8.8
Detroit River							
Fighting I.	27	2.2	0.04	0.05	0.06	13	7.5
Lake Huron							
Chantry I.	3.1	0.77	0.05	0.03	0.15	12	8.7
Double I.	7.1	2.4	0.14	0.04	0.25	18	8.8
Channel/Shelter I.	28	7.0	0.09	0.08	0.15	78	8.2
Lake Superior							
Granite I.	7.2	2.4	0.05	0.06	0.34	16	7.6
Agawa Rock	6.8	2.6	0.09	0.04	0.33	19	7.5
Lake Michigan							
Big Sister I.	9.9	4.7	0.03	0.04	0.58	10	8.7
Gull I.	9.4	5.0	0.04	0.05	0.53	11	8.8

1. Data are mean values based on individual analyses of a 10-egg pool for each colony.
2. All values are in parts per million except dioxin (2,3,7,8-TCDD) which is in parts per trillion.
3. PCB mixtures are made up of as many as 209 congeners. PCB congeners refers to the total of 41 different individual PCB congeners analyzed separately. This gives a more accurate measurement and can be used by researchers to note the presence of the most toxic congeners.
4. The percentage lipid content of each egg is used as a way to standardize concentrations of these lipophilic contaminants.

Source: Canadian Wildlife Service, Environment Canada.

Eggs from other species of birds have not been collected as systematically as the herring gull. Limited data for the double-crested cormorant, black-crowned night-heron and caspian tern also suggest a general decrease in organochlorine residue levels in eggs collected between 1971 and 1989.

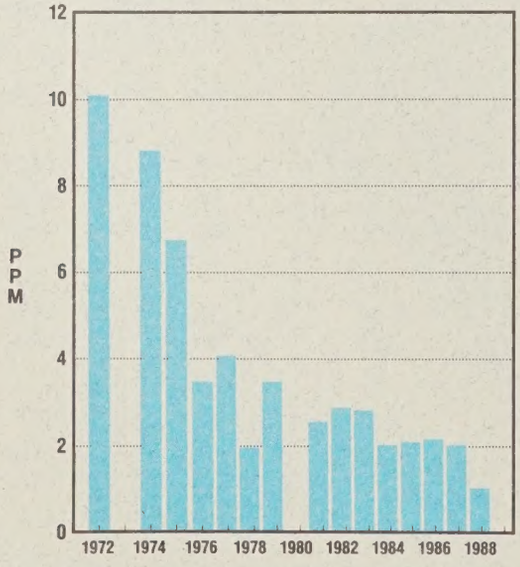
Table 5 shows contaminant levels from the 13 herring gull colonies in 1989. Data from eggs analyzed reveal that a number of organochlorines are distributed throughout the entire basin. Eggs taken from colonies on Saginaw Bay, Lake Huron, the Detroit River and Lake Erie have the highest levels of PCBs. Eggs from Lake Ontario and Saginaw Bay have the highest dioxin residues. Levels of dioxin (10–20 ppt) in eggs from the other colonies in the basin are maintained by atmospheric deposition. Combustion is the most likely source of these "background levels". The declines in levels of pesticides witnessed during the 1970s are mainly due to the restrictions of their use in Ontario and the American states in the Great Lakes basin. Between 1969 and 1974 uses of DDT, aldrin, dieldrin and hexachlorobenzene were severely restricted. In 1976, mirex releases from production and distribution plants on the Niagara and Oswego rivers respectively ended with the restriction of the commercial use of this chemical. Regulations restricting PCB use and manufacture began in 1977.

Levels of contaminants in herring gull eggs will likely remain constant well into the 1990s. Continued atmospheric deposition from sources often outside the basin, resuspension of sediments, leachate from waste dumps, and the remaining sources of direct discharge of toxic chemicals account for the levelling off of the downward trends witnessed for the organochlorine chemicals in the 1980s.

Fish Consumption Criteria

The biomagnification of contaminants through successive levels of the food web can make fish unsuitable for human or wildlife consumption. There is a direct relationship between the lipid (fat) content of a fish species and the concentration of organochlorine contaminants in its tissues. Salmon, trout, carp and catfish have relatively higher levels of organochlorine contaminants than low lipid species such as walleye, northern pike and yellow perch. Older fish also have a longer exposure to contaminants (eight-year-old fish are common in Lake Ontario). In addition, the lipid content of a fish increases with age. Accordingly, organochlorine contaminant concentrations found in a fish are a function of its age and the lipid content of its tissues.

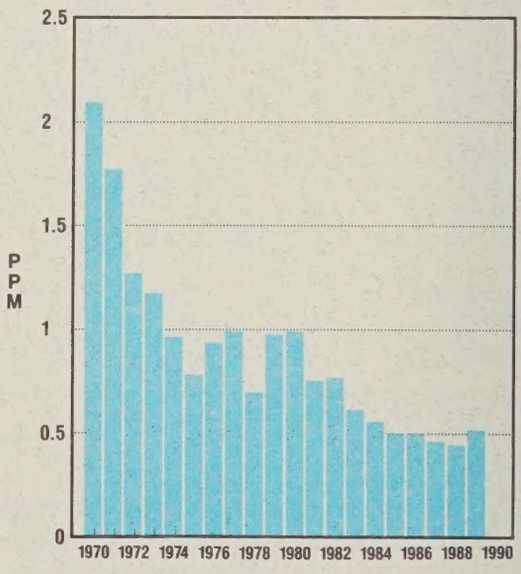
FIGURE 10. Average PCB Concentrations in Lake Ontario Coho Salmon Collected from the Credit River, 1972–1988



No data were collected in 1973 and 1980.

Source: Ontario Ministry of the Environment.

FIGURE 11. Average Mercury Concentrations in Walleye Collected from Lake St. Clair, 1970–1989



Source: Ontario Ministry of the Environment.

Note: Data for Figures 10 and 11 were obtained through the sport fish monitoring program and are useful in assessing overall trends in contaminants. The numerical values are the average contaminant concentration of fish of various ages and should not be used to compare individual years.

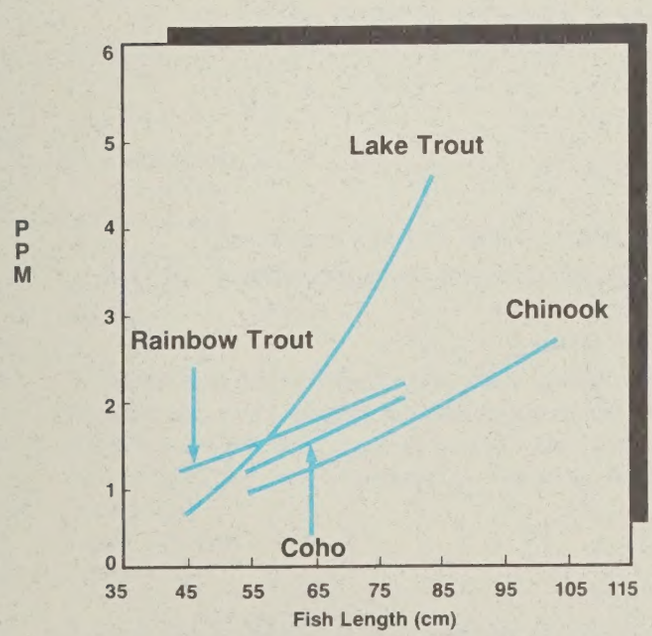
Under the Sport Fish Testing Program of the Ontario government, fish have been collected and analyzed since 1976 for toxic contaminants. Laboratory analyses are carried out on lean, skinless dorsal muscle tissue samples. Similar programs are conducted by the eight Great Lakes states, however, the skin is retained in samples used for analyses in some states. The province issues an annual summary of these data in diagrammatical form for anglers in its *Guide to Eating Ontario Sport Fish*. A variety of fish species are selected from a large number of locations on a rotation basis in Ontario. In the 1990 edition, nearly 200 locations in the Great Lakes are listed and advice on the frequency of consumption is given based on the species and its length. The guide makes more stringent recommendations for children and women of childbearing age. As part of the program a few locations are sampled every year. Figures 10 and 11 show PCB and mercury concentrations in fillets of coho salmon from Lake Ontario and walleye from Lake St. Clair over two decades.

While recent "averaged" concentrations are now slightly below the guidelines set for these persistent toxic substances, older fish are found to have higher concentrations of these contaminants. Figure 12 (a) shows the relationship between fish length and PCB concentrations found in four salmonid species from the Credit River which enters Lake Ontario. The variation in contaminant levels is accounted for by the age of the fish. Lake trout have a slower growth rate than the other species and have been exposed for a longer period of time than other species of fish of the same length. Figure 12 (b) shows that chinook salmon from Lake Ontario have higher concentrations of PCBs than fish of the same length taken from other Great Lakes locations.

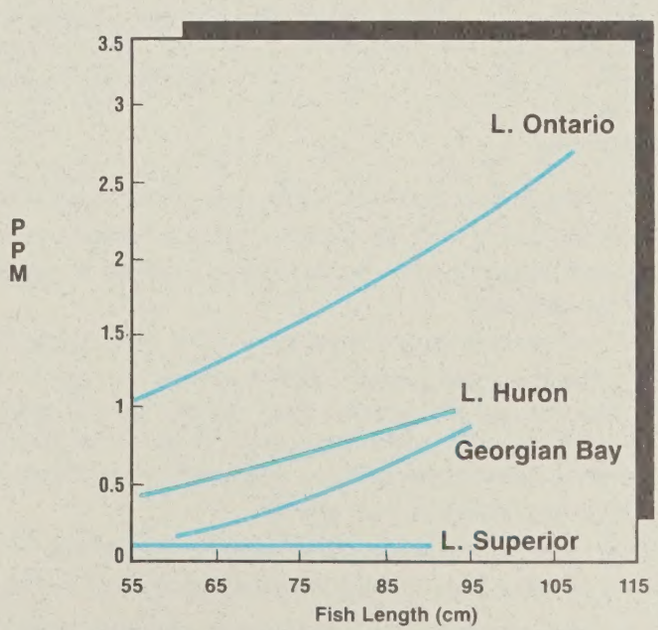
In 1985 more than 4 million people fished in the Great Lakes basin. The economic value of the sport fishery is estimated at $4 billion.

FIGURE 12. PCB Concentrations in Great Lakes Sport Fish of Different Lengths

(a) Four Salmonid Species from the Credit River, Lake Ontario



(b) Chinook Salmon from the Great Lakes



Note: These simplified representations are presented to show that concentrations of chemicals in fish vary between species and between locations. As in the previous figure, the numerical values should not be used to make individual comparisons.

Source: Ontario Ministry of the Environment.

Table 6 lists fish consumption criteria developed in the 1960s by the Canadian and U.S. federal health agencies for the protection of consumers of fish. In Canada, the Department of Fisheries and Oceans fish inspection program ensures that contaminant levels in fish species caught commercially in the Great Lakes and processed in registered fish processing facilities do not exceed guidelines set by Health and Welfare Canada.

A fish fillet is used as the basis to calculate a person's ingestion of contaminants. In Canada, fish consumption advisories are developed by determining the Tolerable Daily Intake (TDI) or the quantity of a chemical that could be consumed on a daily basis, for a lifetime, with reasonable assurance that health will not be threatened. The TDI is based on all available animal and human toxicology data and the application of safety factors. The next step is to determine the Probable Daily Intake (PDI) of the chemical contaminant. The PDI is based on a person's exposure to the chemical from all sources. All foods that may contain the substance are identified and those that may contribute more of the contaminant than others (e.g., fish) are carefully evaluated. The PDI values take account of average and high consumption rates; they also consider the potential exposure of more sensitive sub-groups of the population (such as children or the elderly). A fish consumption guideline may be proposed if the Probable Daily Intake of a chemical is greater than the Tolerable Daily Intake.

Safety factors are included when fish consumption guidelines are established because of uncertainties about the relationship between exposures and effects. There are differences among Great Lakes jurisdic-

TABLE 6
Fish Consumption Criteria[1]
(parts per million, wet weight except dioxin, parts per trillion wet weight)

Parameter	Great Lakes Water Quality Agreement Specific Objective[2]	Health & Welfare Canada Regulatory Limit[3]	U.S. FDA Action Level[4]	Ontario Sport Fish Consumption Guideline[5]
Aldrin/Dieldrin	0.3	0.1	0.3	—
DDT (total)	1.0[6]	5.0	5.0	5.0
Dioxin (2,3,7,8-TCDD)	—	20 (ppt)	25[7] (ppt)	20 (ppt)
Endrin	0.3	0.1	0.3	—
Heptachlor/Heptachlor Epoxide	0.3	0.1	0.3	—
Hexachlorobenzene (HCB)	—	0.1	0.3	—
Kepone	—	0.1	0.3	—
Lead	—	—	—	1.0
Lindane	0.3	0.1	0.3	—
Mercury	0.5[6]	0.5	1.0	0.5[8]
Mirex	Substantially absent[6]	0.1	0.1	0.1
PCBs	0.1[6]	2.0	2.0	2.0
Toxaphene	—	0.1	5.0	—

1. Criteria based on skinless fillet unless otherwise footnoted.
2. Based on the protection of the most sensitive species, which accounts for lower values for some compounds.
3. HWC regulatory limits apply to fish in commerce only. The Province of Ontario applies these as guidelines to sport fish consumption.
4. U.S. Food and Drug Administration (FDA) action levels based on fillet with skin on.
5. Ontario guidelines refer to restricted frequency of consumption of fish: If level of a single contaminant in a skinless dorsal fillet is below the guideline then unrestricted consumption is allowed; if the level exceeds the guideline then restriction in frequency of fish meals is advised. For women of child-bearing age and children under 15 years, restrictions apply below the guideline levels and no consumption is recommended for levels that exceed the guideline.
6. Criteria based on whole fish.
7. No consumption where TCDD levels exceed 50 ppt.
8. No consumption is recommended if the level for mercury exceeds 1.5 ppm.

A number of studies have shown that reduction of fat in fish flesh can decrease the amount of fat-soluble contaminants in the portions of fish consumed. Fats in fish flesh can be reduced by trimming fatty areas, puncturing or removing skin prior to cooking, cooking so that fats are drained (e.g., baked, broiled or grilled on a rack), or deep frying. These methods do not reduce the mercury content in fish flesh since this chemical is stored primarily in muscle tissue (fillet).

tions in the guideline levels set for fish consumption advisories. This has caused confusion. In response to a public demand for clarification, there is at present an exercise under way to standardize fish consumption guidelines among U.S. states.

Depending on contaminant levels found, fish sampling at the same location in Ontario is done every three years or less. Although not statistically rigorous, the presence or absence of an advisory on a lake-wide basis is revealing. The percentage of sampling locations on Lakes Ontario and Superior with advisories for lake trout have remained constant since 1983; but there has been a decline in the percentage on Lake Huron. In 1989 all Lake Ontario sampling locations for lake trout and chinook salmon had consumption advisories. These fish all have a high lipid content and are top predators. On Lake Superior, 100 percent of the sites for siscowet, a subspecies of lake trout, and walleye had advisories. Many of the Lake Superior advisories are for mercury which is a natural contaminant of this watershed. For yellow perch the percentage of locations with advisories is lower on all lakes but declining in only Lakes Erie and Ontario. Yellow perch have lower lipid levels and are lower in the food web than trout.

A Catalogue of Effects

Earlier in this chapter, information was provided showing that specific organochlorine chemicals have accumulated in the plankton, fish and eggs of birds in the food web of the Great Lakes. While a great deal is known about the trends of persistent toxic chemicals and their distribution in the Great Lakes basin, the full biological significance of their presence in the ecosystem remains the subject of ongoing research.

To date, there is published scientific evidence that 11 wildlife species, all top predators, have exhibited population declines, reproductive effects and/or other physiological problems related to persistent toxic substances since the 1960s. These effects are summarized in Table 7. There are also unpublished records of effects for several other aquatic species (osprey, great blue heron, Virginia rail). It is encouraging to observe that on a lake-wide basis, the majority of bird species have experienced significant recoveries in their reproductive success. The exceptions are the bald eagle and the common and Forster's tern. Field biologists are still observing manifestations of developmental toxicity in species on Lakes Michigan, Superior, Huron and Ontario. These difficulties are

TABLE 7
Species of Fish and Wildlife Known to be Affected by Contaminants in the Great Lakes[1]

Species	Population decrease	Effects on reproduction	Eggshell thinning	Congenital malformations[1]	Behavioural changes	Biochemical changes	Mortality	Alterations in recruitment
Mink	X	X	NA	NE	NE	NE	X	?
Otter	X		NA	NE	NE	NE	?	?
Double-crested Cormorant	X	X	X	(X)		X	?	?
Black-crowned Night-Heron	X	X	X	X		X	?	?
Bald Eagle	X	X	X	NE		NE	NE	?
Herring Gull		X	X	X	X	X	X	
Ring-billed Gull				X		NE	X	
Caspian Tern		X		X	NE	NE		X
Common Tern		X	X	X		X		
Forster's Tern		X		X	X	X		
Snapping Turtle	NE	X	NA	X	NE	NE	NE	NE
Lake Trout		X	NA			X		
Brown Bullhead			NA			X		
White Sucker			NA	X		X		

X = effects documented
NA = not applicable
NE = not examined
? = suspected since population declined

1. Unpublished records of congenital malformations (gross birth defects) exist for the double-crested cormorant, great blue heron and the Virginia rail.

FIGURE 13. Birth Defects Reported in the Young of Great Lakes Fish-Eating Birds, 1971-1985

Location	Time Period	No. of Species	Number of Individuals
Lake Superior			
1. North Shore	1971-75	1	1
	1976-80	1	1
Lake Michigan			
2. Green Bay	1971-75	3	3
	1976-80	3	3
	1981-85	4	53
3. Straits of Mackinac area	1976-80	1	1
Lake Huron			
4. North Channel	1976-80	1	1
	1981-85	3	3
5. Georgian Bay	1976-80	2	2
	1981-85	1	2
6. Thunder Bay	1971-75	2	6
7. Central Basin	1976-80	1	1
Lake Erie			
8. Detroit River/Western Basin	1971-75	1	1
	1976-80	1	1
9. Eastern Basin	1971-75	1	2
Lake Ontario			
10. Western Basin	1971-75	1	8
11. Bay of Quinte	1971-75	3	5
	1976-80	4	3
	1981-85	1	1

See Table 7 for a list of affected bird species.

Source: Canadian Wildlife Service, Environment Canada.

the most severe in highly contaminated areas such as Green Bay on Lake Michigan, Saginaw Bay on Lake Huron and Hamilton Harbour on Lake Ontario.

Deformities

Congenital malformations (birth defects) provide gross visible evidence that young birds and turtles are affected during their development. Field biologists have noted that in healthy wildlife populations birth defects are uncommon. Over the past 20 years, birth defects have been reported in ten species of Great Lakes fish-eating birds (see Figure 13). If malformations were to be monitored in a systematic way, their occurrence and prevalence could serve as indicators of biologically significant levels of developmental toxins in the food web.

The reported malformations occur in locations heavily contaminated with PCBs and other organochlorine compounds. There are clusters of birth defects involving several species.

1) In Lake Ontario, defects were particularly prevalent in the early 1970s in six species which breed there.
2) In Lake Huron, deformities have been found in the North Channel, Georgian Bay and offshore from Alpena County, Michigan.
3) In Lake Michigan, deformities have been found in several species and markedly elevated rates of bill deformities have been found in young cormorants in the 1980s.

A study of Forster's terns in Green Bay found no evidence that infectious disease could account for the poor survival of embryos, birth defects in young or the abnormal physiological functioning. It was concluded that organochlorine chemicals were involved.

Tumours in Fish

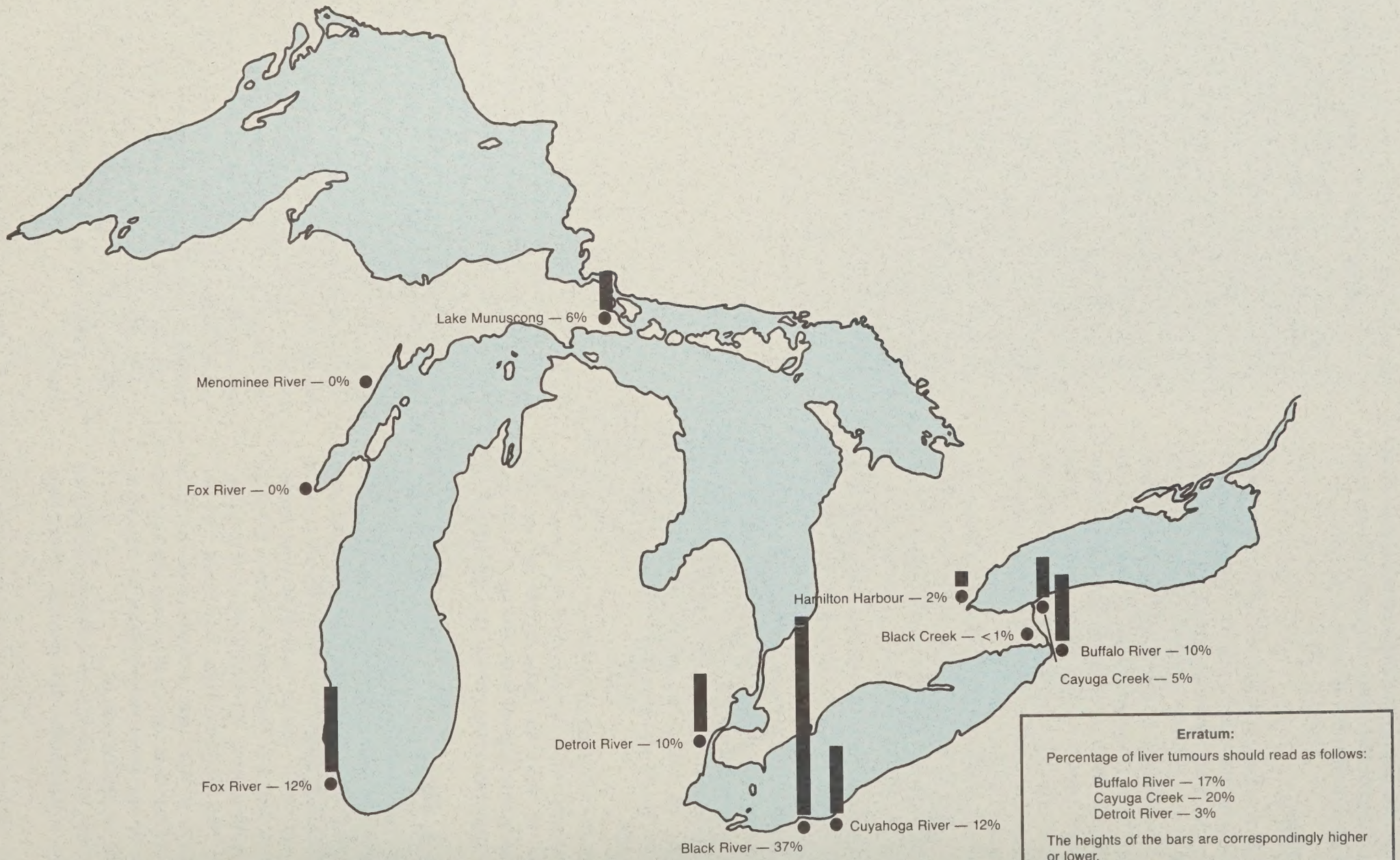
A field study conducted between 1967 and 1972 using 17 species of fish concluded that the increased prevalence of tumours in the Fox River, Illinois, was correlated with the degree of chemical pollution. In 1982 liver tumours in brown bullheads were associated with high levels of carcinogenic PAHs found in the bottom sediments of the Black River, a tributary of Lake Erie. This contamination was caused by discharges from steel and coke industries in the area. The brown bullhead is now used across the basin as an indicator of chemical carcinogens in nearshore areas and connecting channels.

Liver tumours were found in white suckers from western Lake Ontario sites surveyed between 1985 and 1987. The presence of tumours in fish in such geographically restricted areas strongly suggests a chemical cause especially since this type of tumour is often associated with chemical exposure. Figure 14 shows the occurrence of liver tumours in brown bullheads and white suckers. Given the large number of contaminants in the Great Lakes it is unlikely that carcinogenesis can be linked to a specific chemical. Despite the difficulties in "proving" that exposure to individual chemicals in the Great Lakes is responsible for tumours in fish, the circumstantial evidence is overwhelming. In the laboratory, known chemical carcinogens have caused liver tumours, and river sediment extracts have induced tumours in fish. In the Great Lakes environment, tumour frequencies are highest at locations contaminated with chemical carcinogens, and fish analyzed are found to metabolize chemicals such as B[a]P into carcinogens. It is reasonable to conclude that the same processes demonstrated in the laboratory are also occurring in the environment.

How Toxic Chemicals Affect Organisms

Toxic chemicals alter the normal biochemical and physiological functions of animals and plants. Effects can occur at the *molecular* level (e.g. enzyme activity, DNA damage), at the *cellular* level (e.g. tumour formation), at the *tissue* level (e.g. eggshell thinning, organ functions), at the *individual* level (e.g., behaviour and survival ability), at the *population* level (e.g., mortality, abundance and distribution), and at the *community* level (e.g., number of species and their interactions). These levels are not independent of each other. For example, when the field biologists observed the decline of bird *populations* in the 1960s and 70s, there was reduced reproductive success of *individuals* and eggshell thinning in a number of fish-eating bird species. Investigation at the *cellular* and *molecular* levels established a cause and effect relationship with the persistent organochlorine pesticide DDT/DDE and the process responsible for eggshell formation. This work was carried out interactively by laboratory experimentation and by field studies.

FIGURE 14 Percentage of Liver Tumours in Fish from Great Lakes Locations
(a) Sampling Locations for Brown Bullheads



Erratum:

Percentage of liver tumours should read as follows:

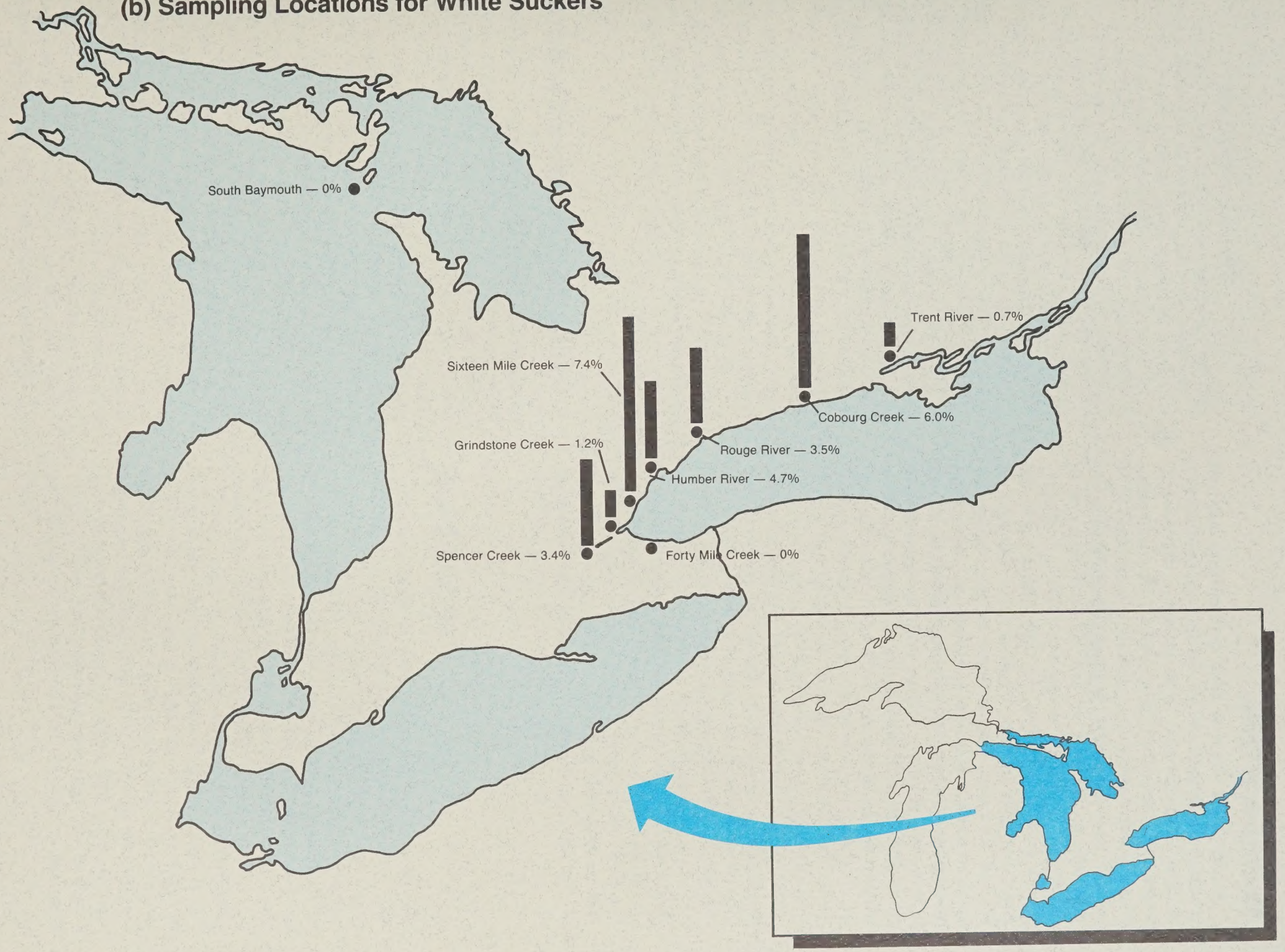
Buffalo River — 17%
Cayuga Creek — 20%
Detroit River — 3%

The heights of the bars are correspondingly higher or lower.

Note: The height of the bar graphs indicates the prevalence (as a percentage) of liver tumors in populations of brown bullheads and white suckers sampled from Great Lakes locations. These data were collected in various years during the 1980s.

Source: Department of Fisheries and Oceans

FIGURE 14 Percentage of Liver Tumours in Fish from Great Lakes Locations
(b) Sampling Locations for White Suckers



Biochemical Tests

An approach has now been developed in fish and wildlife toxicology to detect changes induced in cells as a result of exposure to chemicals in the environment. These are called "biomarkers". If normal physiological functioning of organisms is a criterion for a healthy environment, then this approach will tell the investigator whether or not the environment is healthy for the species being studied. The herring gull, cormorant and tern are Great Lakes birds presently most amenable to these types of tests. Changes in thyroid function, the activity of liver enzymes involved in detoxification, synthesis of heme in the liver and retinol (vitamin A) storage have been used. In fish, two enzymes (mixed function oxidase and amino levulinic acid dehydratase) found in all species are used to assess health.

Dioxin Equivalents

The term dioxin refers to a group of 75 similarly structured compounds known as congeners. The most toxic dioxin congener, 2,3,7,8-TCDD, activates enzyme systems associated with the detoxification of chemicals in the liver of laboratory rats. The induction of one of these enzyme systems has been strongly correlated with reduced body weight (wasting), abnormal thyroid gland function, changes to the immune system and deformities in test animals.

2,3,7,8-TCDD induces liver enzyme activity more than any other compound on a weight basis. In the algebra of dioxin equivalents, it is assigned a value of one. PCBs, furans, and other dioxin congeners are assigned values based on their toxic potential relative to 2,3,7,8-TCDD. Analysis of eggs of Great Lakes Caspian terns and double-crested cormorants have found a direct correlation between dioxin equivalents and levels of embryo mortality.

4

Accounts of Great Lakes Species

There are three fish, one reptile, eight bird and two mammal species (Table 7) for which exposure to toxic chemicals has been linked to reproductive or other physiological problems. Two of the species, brown bullheads and white suckers, are bottom-dwelling and bottom-feeding fish. All of the wildlife species are long-lived and they feed either predominantly or almost entirely on Great Lakes fish. As part of the Great Lakes food web, humans share a position atop the food web with the bald eagle (Figure 2).

The following accounts review data on the concentrations of persistent toxic chemicals and the associated effects in seven of these species.

Double-Crested Cormorant

The best estimates of the total Great Lakes population of cormorants in the early 1950s were under 1000 pairs of birds. By the 1970s, populations had crashed on all Great Lakes except Lake Erie. On Lake Ontario there was no known successful breeding of cormorants between 1954 and 1977, while on Lakes Michigan and Superior, cormorants failed to breed by the early 1960s and 1970s respectively. This reproductive failure was the result of broken eggs or the failure to lay eggs. Most of the breakage occurred due to the marked thinning (15%–20%) of the eggshells induced by the pesticide DDT. Cormorants are particularly sensitive to eggshell thinning because they incubate their eggs by standing on them. Cormorant populations have since recovered and the increase in cormorant nests after 1980 coincides with the decline of DDT/DDE concentrations in their eggs.

The cormorant story has recently taken an interesting turn. Currently there are more than 20 times the number of cormorants nesting in the basin than at any time in this century. While the cause of this population explosion is unknown, the present-day ecosystem is clearly advantageous to the cormorant's success.

Since the resumption of successful breeding, field biologists have observed a range of deformities in young cormorants. The prevalence of chicks with bill defects is a particular concern because these developmental defects are initiated when chicks are still inside the egg (see cover photograph). Markedly elevated rates of occurrence of bill defects are found in Green Bay, and overall rates are slightly higher in the Great Lakes cormorants compared to those from relatively non-contaminated environments.

These findings link a birth defect with the highly contaminated food chain of this species. PCBs and related compounds are likely responsible. Although data are limited, present PCB levels in Lake Ontario cormorant eggs appear to be unchanged from the early 1970s.

Bald Eagle

The bald eagle is a long-lived top predator species feeding on large fish, gulls, waterfowl, turtles and muskrats. By being at the top of the Great Lakes food web, the species is particularly vulnerable (see Figure 2). Bald eagles tend to occupy the same breeding areas year after year and thus are affected by local environmental contaminants. They may also migrate to polluted areas outside their breeding season.

Shortly after the widespread introduction of DDT in 1946, an amateur naturalist noted that many eagles in Florida had failed to nest and that their eggs did not hatch. Following an investigation of the remaining eagle populations, the U.S. Fish and Wildlife Service declared the southern subspecies "endangered" in 1967. The bald eagle was probably the first bird species known to be affected by the widespread use of DDT.

TABLE 8
Concentrations of Organochlorines in Eggs[1] from Bald Eagle Nests in the Great Lakes Basin, 1986-1988

Year	Site	Residue Concentration		
		PCB[2]	DDE	Dieldrin
Shoreline				
1986	Lake Michigan (Big Bay de Noc)	51–60	26–35	14–22
1986	Lake Erie (Sandusky Bay)	8.6–44	2.3–10	0.25–0.69
1986	Lake Huron (Thunder Bay)	96–119	38–44	2.2–2.4
1986	Lake Superior (Whitefish Bay)	12.9–14	2.4–9.5	0.18–0.51
Inland				
1986	Lake Michigan (Menominee River)	2–29	1.1–16	0.08–0.9
1986	Michigan (lower peninsula)	12–14	5.2–6.2	0.24–0.26
1988	Michigan/Wisconsin border	2.4–13	0.48–2.7	0.06–0.09
1988	Ohio	5.7	1.5	0.07

All values are in parts per million.

1. A total of 24 eggs were collected from 14 sites over 3 years.
2. PCB concentrations based on analysis using Aroclor mixtures and are not directly comparable to the PCB congener values for herring gulls in Table 5. For an approximate conversion multiply Aroclor values by 0.5.

Source: U.S. Fish and Wildlife Service.

In the Great Lakes region, the introduction of persistent toxic chemicals led to a drastic decline in eagle populations. Historically, there were at least 90 locations where eagles nested on the Canadian shoreline. During the 1960s and 1970s, only ten active sites were found on the lower lakes between Lake Huron and the St. Lawrence. During the 1969 and 1974 period, field data show that only nine young fledged, all on Lake Erie. Along the U.S. shoreline, fewer than 30% of eagle nesting attempts resulted in fledglings leaving the nests. Analysis of eagle eggs collected from nests during the 1970s suggested that DDE was the causative agent in eggshell thinning and the impairment of reproduction. Although no eggs were collected from the Great Lakes shoreline nests during this study, biologists have correlated the presence of DDE with the lack of reproductive success. Another pesticide, dieldrin, played a role in adult mortality.

Because of the endangered/threatened status of this species in both Canada and the United States, it has not been possible to carry out systematic egg collections. Data on contaminant levels have been obtained by analyzing eggs which have failed to hatch. Levels of PCBs, DDE and dieldrin are equal to or higher than those found in herring gull eggs in the same area. This is not surprising as bald eagles may feed on herring gulls and contaminated waterfowl as part of their diet. Data from U.S. locations collected between 1986 and 1988 are given in Table 8. An important feature of these data is that residue levels of DDE, PCBs and dieldrin are significantly higher in eggs obtained from shoreline nests than from inland sites. At present there are insufficient data to discern temporal trends but contaminant levels are high enough to cause embryo mortality.

It is encouraging that eagle populations have begun to recover in some parts of Ontario and in several U.S. states following the restriction in agricultural use of DDT; however, researchers have cautioned that since the bald eagle is a long-lived species, survival of the young to breeding age may be more important than nesting success itself. Observations during the 1980s on the U.S. side of the Great Lakes show that many pairs of eagles are now able to nest, but they are unsuccessful in producing offspring.

In recent years, there has been an expansion of eagle populations along the Canadian Lake Erie shoreline. More and more attempts to breed are suc-

cessful, reflecting the lower concentrations of organochlorine pesticides in Lake Erie fish and waterfowl. On Lake Ontario, no nesting attempts have been recorded even in areas which still have suitable habitat.

Given that the bald eagle feeds on species which are also consumed by anglers, hunters and aboriginal people, its health may be a useful surrogate for humans. In addition, its position at the top of the food web and high sensitivity to toxic contaminants make it a candidate for ecosystem indicator. The return of normally reproducing eagle pairs to their former habitat and the expansion of their population should also serve as the biological definition of the "virtual elimination" of persistent toxic substances from the Great Lakes ecosystem. In relatively uncontaminated environments, individuals of this long-lived species return to the same nesting location year after year.

Herring Gull

As noted earlier, the herring gull has been routinely used as an indicator species of Great Lakes contaminant levels since 1974. The herring gull's ability to bioaccumulate persistent toxic chemicals while remaining relatively insensitive to the toxicity of these chemicals makes it valuable for the measurement of levels and trends. Wildlife biologists have also utilized this species to measure biochemical changes from contaminants. This is significant now that contaminant levels have declined somewhat and there are generally fewer observable deformities in birds. Alterations in biomarkers indicate that PCBs and other organochlorine chemicals continue to be present in sufficient quantities in Great Lakes fish to influence the physiology of the herring gull over much of the basin. The experimental use of this animal may bring us closer to establishing cause and effect relationships between toxic chemicals other than DDT and wildlife.

As early as 1964, colonies of this species on Lake Michigan suffered reproductive problems; by 1970, Lake Ontario colonies also had similar problems. In contrast to cormorants, eagles, common terns and black-crowned night-herons, herring gulls did not experience critical eggshell thinning. Instead, a different pattern emerged: there was a high embryo mortality and a high loss of eggs due to lack of attentiveness of the adults incubating the eggs.

By 1978, productivity had increased in both Lakes Ontario and Erie to levels that ensured stable populations. Currently, populations are once again thriving. Herring gulls on Lakes Huron and Superior did not experience the depressed levels of productivity observed in colonies on the other lakes. These findings are consistent with the lower contaminant levels in the food web of these lakes. The pesticide DDT and its metabolite DDE are known to mimic the female hormone estrogen and male embryos can be feminized experimentally by doses of these compounds. In a retrospective analysis, herring gull embryos that were preserved from the mid-1970s were examined. A portion of the male embryos were found to be significantly feminized, and the female embryos had enlarged oviducts. The significance of these findings is unclear.

Common Tern

There is a good deal of concern for the common tern in the Great Lakes. Recently, the Committee on the Status of Endangered Species in Canada began to review its status. While the common tern has certainly been affected by the contamination of the aquatic food web, the high lake levels of the last 20 years have forced this species to abandon its preferred nesting habitat of gravel islands. Terns are now nesting on artificial sites, but these are subject to human disturbances and wildlife predators. In 1987, common tern populations in Lake Ontario were the lowest recorded in history.

In 1970, a field biologist with Environment Canada discovered that something was fundamentally wrong with the common tern colonies in Hamilton Harbour on two of these artificial sites. While some young of varying age were found in the nests, the eggs in most had failed to hatch. On examining one of those eggs, he found that the young chick had died before it could completely crack open the shell. Several other eggs contained dead embryos. At the edge of a grass tussock, the biologist also noticed an abnormal two-week-old chick, its upper and lower bill crossing over without meeting — a deformity which would result in certain starvation. A systematic study of these and other colonies confirmed that colonies on Lakes Ontario and Erie were reproducing poorly due to contaminant toxicity to embryos. The prevalence of birth defects in the five Lake Ontario colonies between 1971 and 1973 is the highest observed in any species in any location to date. Data show that PCB and DDT levels have decreased in eggs of this species. A severely deformed common tern embryo was found in Hamilton Harbour as recently as the 1989 field season and

chicks in Saginaw Bay and Green Bay continue to suffer from contaminant-related effects.

The common tern is sensitive to the reproductive effects of persistent toxic contaminants and faced with a variety of threats, its future survival on the Great Lakes remains in question.

Mink

Mink, otter and muskrat are aquatic mammals exploited by humans for the commercial value of their fur. Scientists have found that these species accumulate organochlorine chemicals in their body tissues. In the 1960s mink raised on fur farms and fed on a diet of Great Lakes fish suffered complete reproductive failure. Detailed laboratory research showed that the causative agent was PCBs in Great Lakes fish. Later research showed that individual PCB congeners with dioxin-like activities were related to the adverse effects in the adults and toxicity to the fetus. Mink are one of the species most sensitive to PCBs, HCB and dioxin poisoning.

Mink are important indicators of contaminant levels in Great Lakes wetlands since they have small home ranges and eat muskrats and other mammals, fish and birds living in the wetlands. They are sensitive to PCBs and relatively insensitive to DDT exposure. Data from five regions of Lake Ontario and five townships bordering Lake Erie show that the distance of the capture from the Great Lakes shoreline is an important factor in determining the extent of contaminant accumulation in mink. Animals captured farther away from the shore do not feed exclusively on Great Lakes fish and generally had lower organochlorine levels. Based on analyses of mink carcasses obtained from trappers, high concentrations of PCBs in the liver were observed along the St. Lawrence River and in the Whitby-Cobourg area of Lake Ontario. Mink from the shoreline had levels of PCBs high enough to suggest that adverse reproductive effects would occur, based on studies of ranch mink.

In the absence of a census of fur-bearing mammal populations along the shores of the Great Lakes and inland, trapping records have been examined to determine whether wild mink populations in high PCB risk areas have declined. The findings are inconclusive. The data from these records are confounded by at least three factors: intensity of trapping, the value of pelts and the destruction of mink in some areas by trappers in order to protect muskrats.

The harvest data of Ontario mink and muskrat (their main prey) between 1970 and 1985 have been recently examined. Two areas of Great Lakes shoreline known to be highly contaminated with PCBs were compared to harvests in two areas of comparable size, one consisting of townships one or two townships removed from the shoreline townships in the high risk group and another of two townships in central Ontario where PCB contamination would be minimal. The two high PCB risk areas had significantly smaller mink harvests than the two low risk areas in 12 out of 15 years. In contrast, muskrat harvests were different in only 7 of 15 years, and in 3 of these years it was the high risk areas that had the larger muskrat harvest.

While this evidence of mink population differences correlated against Great Lakes shoreline residence is largely circumstantial, it is consistent with the pattern observed in another aquatic mammal, the river otter. The diet of the river otter is predominantly fish. In this species, rivers where inland stretches support healthy populations in Michigan and Wisconsin become sparsely populated as they approach Lake Michigan. There is a similar pattern in the bald eagle with inland populations recovering and shoreline nesting largely unsuccessful.

Common Snapping Turtle

The common snapping turtle eats mainly fish, plants and insects, and since these foods can accumulate contaminants, the turtle itself and its eggs become contaminated. Pollutant levels can become quite high in the fat, liver and eggs of snapping turtles. This species is long-lived and restricts itself to a small area throughout the year, which makes it a useful indicator of local contamination. Snapping turtles are common throughout eastern and central Canada and the United States. This makes comparison of contaminant levels in the turtles possible among many areas.

In the 1980s, snapping turtle eggs were collected from ten locations in Ontario and two locations in Quebec and analyzed for the presence of PCBs, organochlorine pesticides, dioxins and furans during three study periods.

In each study period, Lake Ontario eggs were generally more contaminated than eggs from Lake Erie, the St. Lawrence River and Algonquin Park. In specific populations in Lake Ontario such as those in Cootes Paradise/Hamilton Harbour and Lynde Creek, eggs

were substantially more contaminated with PCBs, dioxins and furans than eggs from elsewhere.

For populations which were studied in both 1984 and the 1988/1989 period, mirex and DDE contamination in snapping turtle eggs had not declined markedly at any site with the exception of Hamilton Harbour. PCB concentrations at Algonquin Park were lower in 1989 than in 1984, while levels from Lake Ontario eggs fluctuated.

Cootes Paradise/Hamilton Harbour is the only site where dioxins and furans have been measured in both 1984 and 1988. Although concentrations of the most toxic dioxin congener declined by 50% at Hamilton Harbour compared to 1984 levels, concentrations of other dioxins and furans are either remaining constant or increasing.

Contaminant levels in turtle eggs have generally not declined and in many cases have increased since 1984.

Between 1984 and 1987, 27 adult turtles from Hamilton Harbour were found in various states of poor health; 22 died from unknown causes in mid-summer, a time of relatively low stress for this species. High residues of PCBs and the pesticides HCB, chlordane and DDE were found in their tissues. Turtle eggs collected from wetlands along Lake Ontario were incubated and deformities in the embryos and hatchlings were observed. These deformities were similar to those seen in Great Lakes cormorants, gulls, terns and fish (bent tails, twisted mouth parts, deformed legs) and were associated with levels of contaminants in the tissues at some sites.

Lake Trout

Commercial harvests of lake trout in the Great Lakes decreased by over 90% between 1930 and 1960. To address this trend fisheries agencies have implemented stocking programs, sea lamprey control (an important predator), quota management and measures for the conservation of fish habitat. Presently lake trout populations in the Great Lakes are maintained by intensive stocking programs and there is evidence of poor recruitment of young fish into the breeding population. Levels of PCBs and DDT for each lake since the 1970s are given in Figure 4.

The effects of chemicals on fish populations are often masked by the effects of non-chemical stresses and the organisms may succumb before the effects of chemical exposure are observed. Mortalities of lake trout (and coho salmon) fry were first reported in Lake Michigan in 1969. Lake trout were studied for 12 years and researchers concluded that chemicals are involved in the reproductive impairment of Lake Michigan lake trout because

a) mortality was restricted to the most heavily contaminated area of the lake;
b) mortality occurred during the "swim-up" stage of life when the trout fry are the most sensitive to chemical exposure; and
c) the syndrome peaked simultaneously in lake trout and chinook salmon fry in 1981.

Subsequently chemical analyses have revealed that there were 167 organic chemicals in the flesh of these fish taken from southern Lake Michigan. Although the evidence strongly suggests chemical causality for the observed lake trout mortality, the responsible chemical or chemicals involved may never be identified.

5

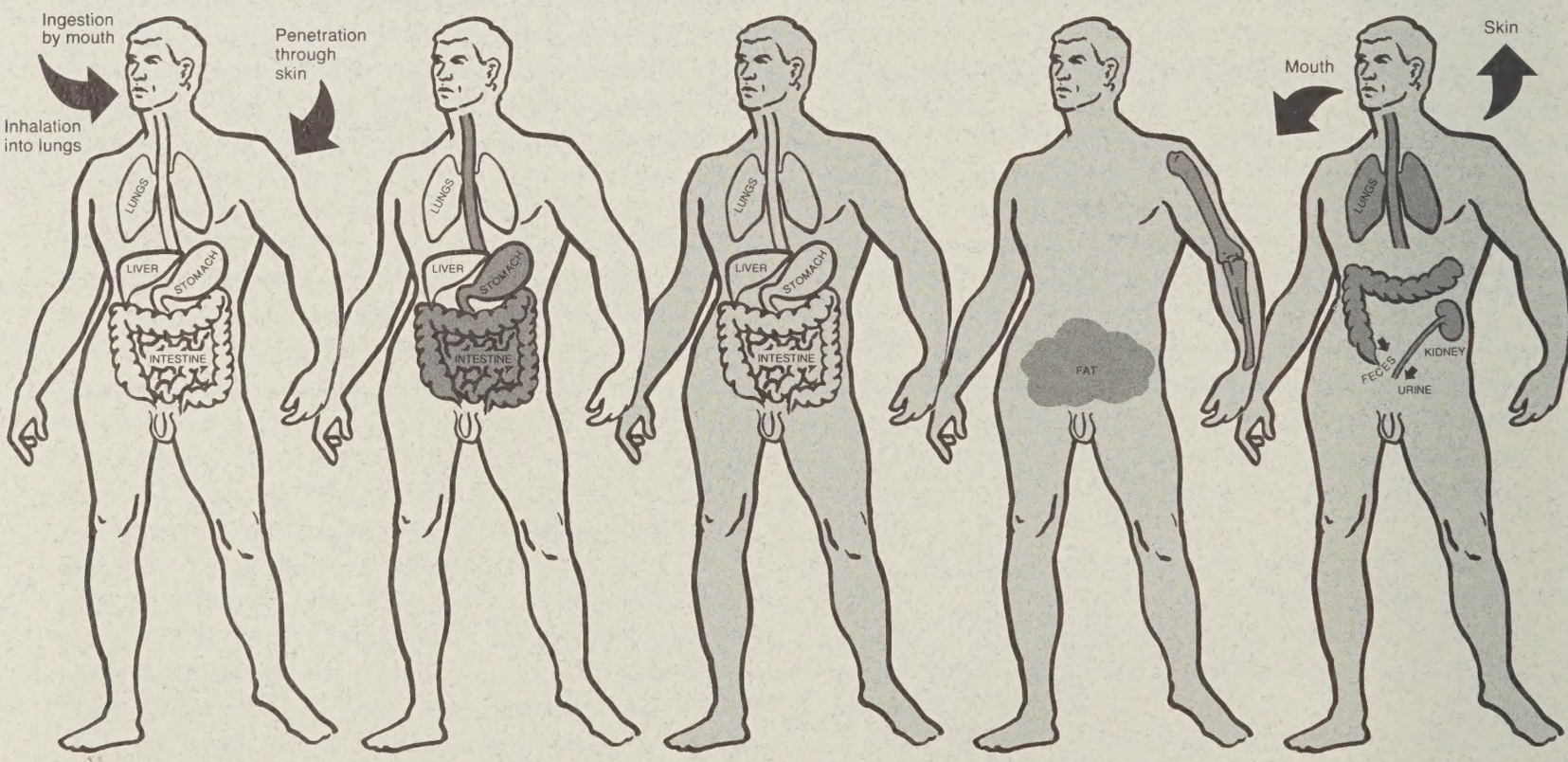
Exposure and Contaminant Levels in Humans

Humans living in the Great Lakes basin ecosystem are exposed to a wide range of organic and inorganic substances. Persistent toxic chemicals come from a number of sources including industrial processes, farms, leaking waste sites and emissions from combustion sources such as incinerators, motor vehicles and industrial activities. Only a portion of our total exposure to environmental contaminants can be attributed to sources in the drainage basin of the Great Lakes. A number of airborne contaminants arrive in the basin from remote sources. Much of the food we consume is grown outside the basin.

Exposure

The routes of exposure to environmental pollutants are from food and beverages, inhalation of air and airborne particulates, from the ingestion of water, body contact with water when bathing or swimming, from inadvertent ingestion of contaminated soil, and from skin contact with airborne particulates. The information presented here on exposure is based primarily on what is known about the intake of specific chemicals from food, drinking water, air and soil. People exposed to pollutants occupationally, including the

FIGURE 15. Intake and Elimination of Contaminants by the Human Body



Contaminants can enter the body through the skin, by mouth or by the lungs.

A chemical ingested by mouth moves through the digestive tract from which it may be absorbed into the bloodstream.

The parent compound or its metabolite may move into all organs and tissues of the body.

The chemical or its metabolite may be stored in bones and fat for long periods of time.

The chemical or its metabolite may be excreted from the body, most commonly through feces or urine, breath and sweat. Breast milk is a significant route of excretion for women.

Source: Adapted from *Toxicology for the Citizen*, Michigan State University, 1987.

handling of contaminated sediments, can accumulate higher levels of these substances than the general population. This report does not address occupational exposures or exposures from acute poisoning episodes. Exposure to persistent toxic chemicals is discussed in the following sections. This report does not discuss exposure to the broad class of volatile organic chemicals, many of which are widespread and toxic.

Food

Chemical residues of persistent toxic substances in food originate from the application of agricultural pesticides and atmospheric deposition on crops. Contamination of Great Lakes fish and wildlife can also arise from agricultural and industrial wastes that enter the waters directly. Although foodbasket studies (food items collected in the supermarket to approximate the Canadian diet) have been carried out in the Great Lakes basin, they are difficult to interpret for several reasons. There has been no agreement on which food items constitute a typical diet and on whether samples should be analyzed before preparation as food or after washing, peeling or cooking. Also, the data presentation varies between studies. The limited data show that food items contain many of the contaminants found in the Great Lakes ecosystem. Estimated dietary intake for each of these substances tends to be far below the acceptable daily intake established for each chemical by the World Health Organization.

The calculation of intake of chemical residues in food for average populations is most often based on an adult diet. These calculations do not adequately account for intakes in populations eating large amounts of sport fish and wild game (e.g., sportsmen and their families and native groups), nor do the majority of studies address the exposure of children. Several factors can increase the intake of contaminants by children and infants. Children usually consume more food per kilogram of body weight and have a higher absorption rate than adults. In addition, breast-fed infants are exposed to higher concentrations of fat-soluble contaminants than those found in adult foods. Although these exposures are for a relatively short period of time, they occur during a critical period of development.

Drinking Water

For most persistent toxic substances, calculations show that drinking water accounts for only a very small percentage of the total daily intake (e.g., less than 1% for dioxins, DDT and PCBs). Most contaminants detected in drinking water are found at very low concentrations and are well below current Canadian drinking water guidelines. In general, fewer than 1% of the samples analyzed by the province of Ontario have detectable levels of the most common environmental organic contaminants. One exception is the agricultural pesticide lindane which is present in approximately 20% of the samples analyzed, but at levels below current guidelines.

A number of non-essential metals are frequently detected in drinking water samples from cities in the Great Lakes basin but at levels below current guidelines. In urban areas there is some variability depending on the age and type of plumbing in use. For example lead can often be detected in household drinking water drawn after several hours of standing in plumbing.

The findings that contaminants are found at very low levels in drinking water are similar to the results of a comprehensive review of Great Lakes drinking water undertaken in 1986 by the Canadian Public Health Association. Contaminant levels in municipal water occasionally may exceed guidelines. This does not imply that drinking water is dangerous to health since guidelines are based on lifetime exposures and have been developed with wide margins of safety. Continued exceedances serve as an alert that there may be an uncontrolled source of a particular chemical.

Air

There are few comprehensive data sets available for levels of airborne heavy metals and organochlorine contaminants that are deposited in Great Lakes water and food. Inorganic lead and copper levels appear to have decreased since 1977 but PCB levels may have increased slightly. Many organic chemicals released into rivers and lakes are volatile and can be transported in air throughout the basin. It is estimated that in some areas of Canada, airborne exposure to furans and dioxins could account for 2% to 8% of the total daily intake of these contaminants.

Soil

Concentrations of contaminants in soil are important because adults and children can be exposed to contaminants found in soil dust. In addition young children may inadvertently ingest significant quantities of soil. Monitoring of contaminants in soil in the Great Lakes basin has not been extensive. Lead levels are highest in urban areas due to the use of leaded

fuels and in particular locations because of industrial activities (e.g., lead battery reclamation and smelting). Elevated soil concentrations are in the parts per million (ppm) range. Soil lead concentrations are likely to decrease with the phase-out of lead in gasoline.

There are few data on concentrations of volatile organics in soil. These compounds would contribute little to the total intake via soil ingestion; they would however contribute to the general airborne exposure.

Total Exposure

The "multimedia approach" is now being used to estimate human exposure from all pathways. This approach to exposure will ensure that total exposure is determined rather than exposure to chemicals in only one medium at a time. Population risk estimates calculated from multimedia exposure analysis are more realistic than risk estimates based on single media exposure.

Multimedia analyses completed thus far indicate that for people in the Great Lakes basin, the majority (80%–90%) of their intake of chlorinated organic chemicals comes from food, a lesser amount from air (5%–10%) and minute amounts from water (less than 1%). Most of the calculations on total human exposure to chemicals in the Great Lakes basin come from the analysis of contaminant levels in drinking water and fish.

Populations Subjected to Increased Exposure

Although drinking water and air contain a wide range of environmental contaminants, these are in low concentrations and thus are not major sources of human exposure to these substances. It is not surprising that food constitutes the main exposure pathway because many persistent toxic substances are fat-soluble and bioaccumulate. There are several subpopulations that are exposed to higher levels of toxic compounds than the general population. When sportsmen and their families and native groups consume from the top of the food web by eating fish (especially in areas where advisories have been issued), waterfowl, or turtles, they are likely to be exposed to higher levels of mixtures of these contaminants. Individuals living in highly polluted locations, such as some cities or industrial areas, are also likely to be more exposed to airborne pollutants. Infants and children consume more food per kilogram of body weight than adults and thus have a relatively higher exposure. Nursing infants in particular can be exposed to far greater amounts of fat-soluble contaminants from their mothers' milk even though it is for a short period of their life. It should be emphasized that despite the presence of organochlorine chemicals in breast milk, the advantages of breast-feeding outweigh the disadvantages to the infant.

Human Tissue Data

The concentrations of a contaminant in tissue can be used as a measure of an individual's exposure. Tissue residues represent the dynamic balance between the intake and absorption of a contaminant and the body's capability to metabolize and excrete the substance (see Figure 15). Studies show that humans have been exposed to many synthetic organic chemicals and metals; a number of these are consistently present in human tissue samples.

In the Great Lakes basin, many ubiquitous contaminants bioaccumulate in resident organisms. For most chemicals this results in increasing concentrations at higher levels of the food web.

Recent improvements in analytical capability resulted in the detection of minute quantities of many chemical contaminants in the ambient environment and in biological samples. As a result, the number of samples that contain detectable levels of these chemicals has increased and a large number of previously unidentified contaminants have been detected. This

does not mean that these chemicals were absent from humans and the environment before the improvements in analytical techniques.

Data on contaminant residues in adipose tissue (fat), blood and breast milk are not sufficient to draw conclusions on trends over the last 20 years, although there is a decline in concentrations of some chemicals found in breast milk. The lack of common laboratory procedures is one obstacle in comparing existing studies. The absence of a long-term monitoring program and a human tissue bank also makes it difficult to determine the extent of exposure and if the exposure is changing over time.

Adipose Tissue

Adipose tissue has been the most frequently analyzed tissue; it is the primary storage site for lipophilic (fat-soluble) contaminants. PCBs and DDE are the most prevalent contaminants and occur at the highest concentrations (usually low ppm). The pesticides dieldrin, lindane, hexacholorobenzene and chlordane occur in human adipose tissue samples throughout North America but at lower concentrations than PCBs and DDE. Dioxins have been found in the low parts per trillion (ppt) range in almost every human fat sample analyzed throughout the world.

Based on the limited data available, it appears that the levels of most contaminants found in residents of the Great Lakes basin are similar to those found in individuals residing elsewhere in North America. There also do not appear to be major differences in the residue levels of individuals from different parts of the Canadian side of the basin. Data are also insufficient to draw conclusions about trends over time in the general population. Data from different studies cannot be rigorously compared because samples have been collected and analyzed using different protocols. In addition, comparisons of human tissue data would be more meaningful if residence, exposure history and (when relevant) cause of death were known.

Blood

Blood serum contains a small amount of fat and has been used to determine concentrations of fat-soluble contaminants in the human body. Blood levels of organochlorine chemicals can be a misleading measure of total body burden because the concentration of a specific contaminant can vary significantly over a few hours. For example, PCB levels can increase dramatically within one hour after the ingestion of PCB contaminated food, reach a maximum ten hours after the meal and return to baseline values within one week as the PCBs are moved out of the blood into the tissues.

There are not adequate data to compare the concentrations of metals such as nickel, copper, cadmium and lead in blood obtained from individuals living within the basin with those of individuals living elsewhere. Factors such as local contamination (e.g., lead smelting, nickel refining), socio-economic status and proximity to urban areas can have significant effects on blood metal concentrations. Levels range from a few parts per million to a few parts per billion (ppb).

Levels of mercury in the blood of some native peoples in the Great Lakes basin have been reported in the "increasing risk" range (20–99 ppb). These levels were similar to findings among Indian residents of a number of other communities elsewhere in Canada. They did not reach the "at risk" levels (over 100 ppb) found in residents of other Ontario native communities known to be severely exposed to mercury contamination, for example, Grassy Narrows and Whitedog, nor in certain Quebec Indian communities (Mistassini and Waswasipi).

Breast Milk

Breast milk has a relatively high proportion of fat and consequently contains many fat-soluble organo-

chlorine chemicals. Three national surveys conducted between 1967 and 1982 found residues of nine organochlorine chemicals or their metabolites in most of the breast milk sampled. In Canada, concentrations of organochlorines in breast milk do not differ significantly in samples taken from different regions. PCB levels in both Canada and the United States did not change noticeably between 1962 and 1982. Levels of dioxins and furans in Canadian samples are similar to those reported in the United States and Sweden (low ppt range).

As with adipose tissue, differences in sampling and analysis protocols make it difficult to compare data between studies and to determine whether the chemical residues measured in these studies are truly representative of Canadian women and consequently the degree of exposure to infants. In addition, contaminant concentrations in breast milk during feeding, between feedings and during the lactation period may vary. For a population of lactating women, the number of previous breast-fed infants, place of residence and life history of exposure to chemicals can also cause variation among samples.

Other Tissues

Tissues such as liver, kidney, brain, muscle and gonad have been analyzed for contaminants. The data available are not adequate to allow meaningful comparisons between residents within the Great Lakes basin and elsewhere. Many metals accumulate in the kidneys. Concentrations are affected by occupational exposure, local contamination, smoking history and socio-economic status. Differences were reported in the concentrations of nine metals in liver and kidneys sampled from cadavers in Kingston and Ottawa, respectively, but donor histories were not available.

Tissue concentrations of lipophilic (fat-soluble) contaminants are largely dependent on the presence of fat in the tissue. Concentrations (on a wet weight basis) of contaminants like PCBs are highest in adipose tissue, followed by liver, kidney, gonad, and brain. Concentrations in the fat extracted from all these tissues tend to be in the same order of magnitude.

Overview of Human Tissue Information

Current data, although incomplete, do not suggest that Canadians living in the Great Lakes basin have higher contaminant levels than those in other parts of the country. Certainly, monitoring programs for contaminants in human tissue have not been comprehensive, have not used similar sampling or analytical protocols and have not taken account of the health and exposure of the donor. If temporal, geographical, gender- and age-related trends in human body burdens are to be determined, a comprehensive sampling strategy should be developed and tissues should be stored for retrospective analysis.

6

Effects of Toxic Chemicals on Human Health

Evaluating Human Health Data

Assessment of the effects of contaminants on the health of populations is complicated by several factors. Frequently, there are insufficient data to determine how much exposure has occurred. Gender, age and lifestyle can all dramatically affect how individuals respond. Humans consume a wide range of foods and beverages and nearly always consume foods grown or produced both from within their community and from elsewhere. Frequently, the types of food and the amounts consumed are seasonal and dependent on sociological and ethnic factors. Finally, humans are nearly always exposed to complex mixtures of environmental contaminants, rarely to single chemicals, and they are frequently exposed to other substances such as medications, alcohol and tobacco products, all of which may interact.

To sort through these difficulties, scientists endeavour to combine the results of studies with human populations and laboratory animals to predict toxic effects associated with exposures. Human epidemiological studies can focus on general populations, occupational groups or individuals with unusual accidental exposures. Some studies consider groups displaying similar adverse effects (e.g., cancer) and look for possible common exposures; conversely, other studies consider common population exposures (e.g., to PCBs) and look for group effects. Each type of study contributes some information but not a complete picture of exposure and effect. Studies with laboratory animals are also useful because, unlike the human studies, experimental conditions can be rigorously controlled, exposure varied through control of dose and detailed biochemical and pathological changes monitored. While most animals, including humans, have similar basic cellular mechanisms, it is important to keep in mind that different species respond in

The effects of contaminants on human populations are dependent on the toxic properties of the contaminants themselves and on the amount, route and duration of exposure. The amount absorbed (dose) is affected by the route of exposure (via mouth, lungs or skin). The magnitude of the effect is dependent on whether it is received all at once, over a long period of time, continuously, intermittently, alone, or in conjunction with other substances.

different ways to the same amount of a contaminant.

Wildlife species in the Great Lakes have been intensively studied. Metabolic, developmental, reproductive, behavioural and immunological effects have been observed across a range of species exposed to mixtures of persistent toxic substances (see Chapter 4). While differences exist in behaviour and exposure between humans and wildlife, these findings are of significance to humans.

The information in this chapter reviews the very sparse data on human populations exposed to a broad range of contaminants in the Great Lakes basin. Appendix I provides summary information on individual contaminants and their most important effects.

"Persistent toxic chemicals due to their nature (ability to cross the placenta, bioaccumulation, occurrence as mixtures, long half-lives, toxic properties) pose threats to the health of individuals within the basin."

Consensus conclusion reached by participants in an international working conference, The State University of New York at Buffalo, 1989

Studies of the General Population

National disease and mortality statistics can provide the basis for one type of assessment of population health. For all types of cancer taken together, the number of cancer cases increased across the North American continent as well as in the Great Lakes basin between 1950 and 1985. This increase is largely due to an increase in lung and skin cancer. These two cancers are associated with cigarette smoking and exposure to ultraviolet radiation. The number of cases per 100,000 population appears also to have increased slightly in North America from the mid-1970s to the mid-1980s.

Cancer is a significant cause of death in North America and the Great Lakes basin. Although the number of cancer deaths per 100,000 population due to all cancers has increased since 1950, it has actually decreased for all cancer deaths other than lung cancer. The Mortality Atlas of Canada (1980) compares cancer mortality of each county to the national average for 1966 to 1976. In the Great Lakes basin there is no obvious indication of any increase in male and female mortality rates for all cancer types when compared to national figures. There is an indication of increased rates in certain Quebec counties bordering the St. Lawrence River. These increases are associated with densely populated municipalities and could be due to several factors including lifestyle and socioeconomic conditions.

There have been very few studies of cancer mortality in specific areas of the Great Lakes basin. In one study in Niagara County, an excess of liver and lung cancer was found in women between 1977 and 1981. There was no association with environmental variables and the determining factor was probably heavy cigarette smoking. There were increases and decreases in the rates of different types of cancer among men in Niagara County; however, there was no consistent pattern and there was no association with the use of Niagara River water.

There have been a few studies of reproductive health in the general population in the Great Lakes basin. Rates of various adverse reproductive outcomes (low birth weight, stillbirth, birth defects) varied in the counties adjacent to and inland from the Great Lakes, although there were no consistent increases or decreases associated with specific areas of the basin. In a study of birth outcomes in five municipalities in the Niagara region, birth outcomes were similar to province-wide results. There were significant increases and decreases in specific congenital anomaly rates, but there was no obvious pattern and no association with environmental variables.

These studies of aggregate populations cannot be used to confirm or deny that there may be adverse effects from exposure to environmental contaminants. Fluctuations in the rates of adverse outcomes (i.e., more than average or less than average) from year to year and area to area are a consistent finding in such studies. There are insufficient data to determine whether or not the incidence of these outcomes in the Great Lakes basin is different from that of other regions in Canada or the United States. There is also inadequate assessment of these effects in communities with greater exposure to Great Lakes basin contaminants through the consumption of Great Lakes fish or drinking water, agricultural or industrial practices or from airborne pollutants.

Studies of Select Populations

Studies of human populations attempt to link exposures to ill-health or death. Some focus on individuals in a group with a common exposure and then establish common health effects (see box); others focus on individuals with similar health outcomes and attempt to determine a common cause (exposure).

Numerous chemical spills which have taken place in the St. Clair River prompted a study of reproductive outcomes in women in this area. Results of this study have not given any indication of major adverse health effects, although there were a decreased number of stillbirths and perinatal deaths and an increased number of low birth weight infants. A more in-depth case-control study has now been completed for the Ontario Ministry of Health. It has concluded that exposure to drinking water from the St. Clair River was not associated with stillbirths, congenital anomalies, low birth weight or infant deaths.

The current knowledge on the health effects of air pollution in the Great Lakes basin is limited. Sulphur oxides and ozone have been linked to increased hospital admissions (for respiratory reasons) and to reduced lung function. These studies were conducted in the Great Lakes basin region but did not account for all pollutants which may affect human health (i.e., metals, organohalogens).

Studies of blood lead concentrations have been carried out in children living in Ontario. Levels reported are similar to those found elsewhere and are declining. Blood lead measures are important because neurological effects have been observed in children and newborns exposed to very low concentrations of lead.

An extensive study of the exposure of Indian residents of Akwasasne to the mix of contaminants in the St. Lawrence River (concentrating on methylmercury, PCBs and mirex as indicator contaminants) and fluoride air emissions from a nearby factory failed to reach any substantive conclusions. Blood levels of contaminants were generally in the accepted normal range or slighly elevated. However, knowledge of the degree of contamination of the fish, air and water did result in serious concern among residents of the community.

A cross-Canada survey of blood mercury levels in native peoples revealed that some individuals in the Great Lakes basin are in the "increasing risk" range. No clinical effects were found in Indian residents of the Great Lakes basin with elevated blood mercury.

Despite the limited number of human population studies to date, these investigations indicate that some groups in the Great Lakes basin have already experienced adverse health effects.

An ongoing study of the children of 242 women who consumed Lake Michigan fish over a six-year period has demonstrated the occurrence of several effects. These women had an average consumption of 6.7 kilograms of fish per year, equivalent to between two and four meals per month. The relationships between fish consumption, PCB levels in the mother's blood, PCB levels in the umbilical cord serum and the effects on the offspring were investigated. Factors other than PCB exposure were taken into account statistically; however, the control group was smaller than the exposed group and there were differences between the two groups of mothers in terms of their use of medication and consumption of alcohol and caffeine.

Initially, a statistical correlation was found between the maximum yearly consumption of Lake Michigan fish and the women's blood PCB levels. No correlation was found between the maximum yearly consumption of fish and PCB levels in the umbilical cord serum. A study of the infants in the group showed statistically significant decreases in their gestation period, birth weight and head size. Based on PCB levels in the umbilical cord, infants were more likely to show "motoric immaturity", more abnormally weak reflexes and a greater amount of "startle". The most highly exposed infants were more likely to be classified as "worrisome".

At seven months, infants were re-tested and showed a statistically significant decrease in their ability to recognize novel visual stimuli; this effect was again associated with increasing cord serum PCB levels. At the age of four, some children of the original group were found to have poorer short-term memory on both verbal and quantitative tests. A separate study of the same group of children demonstrated that PCBs were still present in the blood of over 50% of the children and that mothers' milk was the primary source of exposure. In statistical terms, prolonged breast-feeding was associated with increases in PCB burdens. While much larger quantities of PCBs are transferred to children through breast-feeding, the transfer of contaminants through the placenta seems more important in terms of the developmental effects noted.

These studies are important because they provide initial evidence of the effects of Great Lakes contaminants on human populations. An unpublished study of the offspring of women who consumed fish from Lake Michigan apparently contradicts the findings regarding weight and size of newborns, however, the available documentation does not contain many details and it is difficult to compare the results with the first group.

Given the implications of the association between environmental contaminants and birth outcomes, further research is needed to clarify the relationships between exposure, contaminant levels and developmental effects in other exposed groups and to more precisely identify the causative agents.

Possible Impacts of Specific Pollutants

> "Fish and wildlife in the Great Lakes basin have been hurt by toxic chemicals and the information on human health ... indicates that people are being affected as well. The scale of effects of toxic chemicals on human health cannot be determined ... but we feel that it is significant and warrants concern."
>
> *Tom Muir and Ann Sudar*

Human beings are exposed to a myriad of chemical contaminants. Information on individual chemicals is important as it enables an assessment of the potential toxic effects of human exposure and possible control of the chemical's use. Summary information on a number of toxic substances identified as critical pollutants by the Water Quality Board of the International Joint Commission is provided in Appendix I. The best possible estimates of exposures of average Canadian consumers to individual chemicals are currently below a level of concern; however, consumption of large amounts of freshwater fish containing PCBs, dioxins, furans, lead, or mercury could pose a significant risk to health. Concentrations of contaminants in Canadian drinking water are usually far below current federal guidelines and in most cases contribute only minor amounts to an individual's daily intake.

Recently, sophisticated studies have been conducted on the adverse effects on health of PCBs, lead, mercury, dioxins and furans. Although the subtle effects reported in these studies on the development of the nervous system in children have not been fully substantiated, there is enough evidence to conclude that some sustained environmental exposures may be injurious.

While there is toxicological information in the scientific literature on chemicals acting individually, there are only a few data on their effects as mixtures. Furthermore, there are only limited data on contaminant levels that can be used for estimating exposure. Assessment of the effects of individual chemicals should be complemented with a consideration of the interactive effects of simultaneous exposure to mixtures of chemicals. Despite the possibility that chemicals in the environment act synergistically (3 + 3 = 7 or more), limited scientific evidence available suggests that the mode of action of a mixture of chemicals within an organism is likely to be additive (3 + 3 = 6) or antagonistic (3 + 3 = 5 or less).

There are often similarities in toxic effects and mechanisms of action between different contaminants of similar families. For example, chlorinated organic chemicals such as PCBs, polybrominated biphenyls, mirex, hexachlorobenzene, dieldrin, DDT, dioxins, and furans all cause enzyme induction and, at sufficient dosage, liver damage. Concurrent exposures to low levels of these contaminants have caused effects in experimental animals and are associated with effects in wildlife populations.

As research tools have become more refined, several subtle effects have been observed at extremely low concentrations. Three of the most frequently described effects associated with synthetic organic contaminants are interference of cell-to-cell communication, enzyme induction and disruption of the control of endocrine hormones. These effects on cellular processes may not immediately threaten health or lead directly to disease or death. They indicate that natural regulatory mechanisms are being activated or suppressed and that some processes are being altered. While the direct implications of these effects in humans are unclear, they are undesirable and support the need to reduce our exposure to substances that cause these effects.

7

Synthesis

The Great Lakes basin is a contaminated ecosystem. Monitoring data collected since the early 1970s show that persistent toxic chemicals are present in the water and sediments, fish, wildlife and humans. These chemicals have been associated with effects observed in the fish, wildlife and the human residents of the basin.

In the 1970s and 1980s, restrictions imposed on the uses of organochlorine pesticides, PCBs and mercury in Canada and the United States led to the reduction of their input to the biosphere; however, organochlorine chemicals, toxic metals and aromatic hydrocarbons are extremely persistent. The overall contamination of the Great Lakes, though lower than in the 1970s, is being maintained at current levels due to the resuspension of contaminated sediments, the deposition of airborne toxics, the slow leaching of contaminants from hazardous waste sites and, possibly, runoff from historically contaminated agricultural land. The uncontrolled discharge from municipal sewage systems during some rainstorms and unregulated or accidental industrial releases also contribute contaminants to the ecosystem. As a result, fish, wildlife and humans in the Great Lakes basin ecosystem will continue to be exposed to contaminants for some time to come.

Laboratory and field studies of fish and wildlife have established that many of the chemicals present in the Great Lakes basin can cause adverse effects in a wide range of species. Non-chemical factors also play a role. The interaction of these factors is even more complex in humans. It is difficult to establish that exposure to a particular environmental chemical caused a particular effect in fish, wildlife or humans. It is common for researchers to confirm associations between exposure and effects. Perhaps the best-known example of a cause and effect relationship is between DDT/DDE and eggshell thinning in fish-eating birds.

Since there are biological similarities between wildlife and humans, wildlife species are useful surrogates in assessing the potential for human health effects. At present, the data suggest that neurobehavioural and developmental effects occur in both wildlife and humans exposed to similar mixtures of toxic substances.

There remains the question whether the health of people living in the Great Lakes basin ecosystem is affected by their continued exposure to persistent toxic substances. While traditional measures of human mortality and disease incidence have not indicated that the health of Canadians is affected by toxic chemicals, there is good reason to believe that exposure to persistent toxic contaminants poses a risk to human health. The precise nature and extent of that threat are at present unclear. The most thorough study of subtle adverse effects in the Great Lakes basin to date has shown that there are adverse effects in the children of women who ate contaminated fish from Lake Michigan. It is clear that there are people who are at greater risk than average because they are either more heavily exposed (e.g., nursing infants and those people who eat large amounts of contaminated fish) or are more susceptible (e.g., the developing fetus, newborns, the elderly and those who are in poor health). These "at-risk groups" must be provided with the means by which they can reduce their exposure.

Lack of full scientific understanding of the behaviour of persistent toxic chemicals in the environment and their modes of action within an organism raises the possibilities that there may yet be new means of exposure and undiscovered adverse effects. While researchers are accelerating studies investigating the relationship between exposure to toxic chemicals and human health effects, it is essential that all sectors of society move to reduce the contamination of the environment.

The goal of virtual elimination of persistent toxic substances in the Great Lakes basin can only be achieved if there is a change in attitude and behaviour on a broad scale. Changes are required in individ-

ual actions, corporate strategies, and regulatory initiatives by government agencies. Actions needed include the cleanup of contaminated areas, the prevention of further contamination through close-looped industrial processes and, more fundamentally, the substitution of substances that are less toxic and persistent than those we currently use.

The convergence of human needs with a respect for all forms of life can lead to a balanced use of the earth's resources. The co-operation of all levels of society is needed to reduce further the concentrations of contaminants in the environment.

Appendix I

Critical Pollutants

Many chemicals have been identified in the Great Lakes basin. While toxicity profiles have been prepared for nearly 200 of these, there are insufficient data on most of these to assess the extent of human exposure. This appendix contains a review of information on the 11 chemicals identified as critical pollutants in the Great Lakes basin ecosystem. Although they are treated separately, their presence as mixtures in the environment is of concern. Assessments regarding the threat to human health of each of these chemicals are based on a consideration of the Tolerable Daily Intake discussed in Chapter 3.

Chlorinated Organic Chemicals

PCBs (polychlorinated biphenyls)

PCBs are a group of chemicals used in electrical and hydraulic equipment, lubricants and in many other fluids because they are chemically stable and heat resistant. They are persistent and ubiquitous in the environment. PCBs will continue to cycle through the environment although they are no longer manufactured and new uses are restricted. It has been estimated that there are more PCBs still in use than have been released to the environment to date. PCBs are found at higher concentrations in top predator fish from the Great Lakes, and one study has found an association between maternal consumption of Great Lakes fish, levels of PCBs in maternal serum and delays in certain measures of neurobehavioural development in the infants. Further research is needed to see if these effects are caused by PCBs or by other chemicals that are often found with PCBs.

Mirex

Mirex is an extremely persistent insecticide. In sunlight, it breaks down slowly to photomirex. Both mirex and photomirex are toxic. Although mirex was never used in the Great Lakes basin for agriculture, it is present in the Lake Ontario food web because of industrial releases into the Niagara and Oswego rivers during its manufacture. All uses in Canada were banned in 1978, as was its use as an insecticide in the United States. Since the 1970s, the levels of mirex have decreased in lake trout and coho salmon; levels in herring gull eggs during this same period have not decreased appreciably. Mirex also has been identified in the tissues of people living in the Great Lakes basin. Exposure to mirex at levels currently found in Great Lakes fish is not a threat to human health provided that fish advisories are followed.

HCB (Hexachlorobenzene)

Hexachlorobenzene is a persistent chemical that was originally manufactured as a fungicide for cereal crops. Its use was restricted in Canada in 1971. It is also generated as a contaminant or by-product in the manufacture of pesticides, and it can be formed during the combustion of substances containing chlorine. This compound is ubiquitous and it is found in the tissues of fish, wildlife and humans from the Great Lakes basin. In the 1970s, levels of HCB were present at low concentrations in fish from the Great Lakes. Consumption of reasonable quantities of fish by adults still leaves a considerable margin of safety in relation to adverse health effects observed from this chemical in experimental animals. The intake per unit of body weight by nursing infants is significantly higher than that by most adults because hexachlorobenzene is often present in breast milk. Current environmental levels of hexachlorobenzene are not a threat to health.

Dieldrin

Dieldrin is a persistent toxic chemical that was used mainly as a soil insecticide. It is no longer manufactured in Canada or the United States, and its use is now restricted to applications for termite control. Levels of dieldrin in the environment have not decreased as much as levels of other pesticides. Dieldrin contin-

ues to enter the aquatic environment as leachate. Current levels of dieldrin in fish from the Great Lakes are not a hazard to human health.

DDT

DDT was introduced into North America in 1946 as an insecticide. Its use was restricted in Canada in 1974 and suspended in 1985. In 1989, the last permitted use was banned. The levels of this chemical and its principal metabolite, DDE, have decreased significantly although concentrations in wildlife and fish have now equilibrated. DDT is still used elsewhere in the hemisphere and may be entering the Great Lakes through atmospheric transportation and deposition. DDE is stored in the fatty tissues of fish, birds and mammals, including humans. DDE was identified as the cause of eggshell thinning in many birds and has since been found to disrupt endocrine hormone metabolism and to change the activity of liver enzymes. Studies have also associated high levels of DDE in breast milk with hyporeflexia in newborn infants, but further investigation is needed to substantiate this finding and to determine if DDE is the causative agent. Current levels of DDT/DDE in Great Lakes fish are not a hazard to human health.

Dioxin (2,3,7,8-TCDD)

The compound 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) is the most toxic member of a group of chemicals known as polychlorinated-dibenzo-p-dioxins (PCDDs). It is highly persistent and bioaccumulates. Dioxins enter the environment as the by-products of industrial processes. The most significant sources are pulp and paper mills using chlorine in the bleaching process and chlorophenoxy herbicide production. Dioxins are released as the result of combustion processes in incinerators and motor vehicles using leaded fuel. As a result, dioxins are ubiquitous in the environment and are found in human tissues. Current average exposures to 2,3,7,8-TCDD and total dioxins and furans are below the Tolerable Daily Intake established by Health and Welfare Canada. Individuals consuming large amounts of freshwater fish contaminated with dioxins and furans increase their health risks. The 2,3,7,8-TCDD congener is an animal carcinogen. Other observed effects include immune suppression, hormonal disruption and developmental problems. Accidental exposures of humans to 2,3,7,8-TCDD have commonly resulted in chloracne. Efforts to control the sources of dioxins must be vigorously maintained because of the effects seen after long-term exposure in rats and monkeys.

2,3,7,8-TCDF

The compound 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF) is a polychlorinated dibenzofuran (PCDF). PCDFs are structurally and chemically similar to PCDDs. They are not produced intentionally and result from some of the same industrial processes listed for PCDDs. In general, 2,3,7,8-TCDF is ten times less toxic than 2,3,7,8-TCDD, but has similar toxicological properties. It also tends to bioaccumulate in fat. Although the total average Canadian exposure to 2,3,7,8-TCDD-like compounds is below the Tolerable Daily Intake, efforts to control the sources of both PCDDs and PCDFs must be vigorously maintained.

Toxaphene

Toxaphene is a contact insecticide that consists of a complex mixture of chlorinated camphenes. It was widely used in the United States on cotton crops until the late 1970s. Between the late 1970s and early 1980s, the use of toxaphene ceased almost completely and its manufacture was banned in the United States in 1982. While there are only limited data available, the current levels of toxaphene in Great Lakes fish are highest in Lake Superior because of continued atmospheric inputs. Nevertheless, toxaphene exposure from average fish consumption is not a hazard to health.

Polynuclear Aromatic Hydrocarbons

Benzo[a]pyrene

Benzo[a]pyrene (B[a]P) is one of several polynuclear aromatic hydrocarbons (PAHs) that are formed by the incomplete combustion of fossil fuels, wood and tobacco, the incineration of garbage, as well as in steel and coke production and coal liquification and gasification. B[a]P is present at high levels in sediments of specific industrialized areas within the basin. The major route of human exposure to B[a]P is through food with minor contributions from air and water. Ingested B[a]P is not associated with an increased human cancer incidence. Inhalation of large amounts of B[a]P can cause cancer in humans especially in occupational exposure. Under laboratory condition B[a]P is an animal carcinogen. The presence of B[a]P in lake and river sediments is associated with a high incidence of liver tumours in fish.

Toxic Metals

Mercury

Mercury is a non-essential natural element and is a ubiquitous contaminant in air, water and food. Food

is the major source of human exposure to mercury. Fish and seafood are major contributors to human intake because of the propensity of organic mercury to bioaccumulate. In the past, mercury was widely used as a slimicide in the pulp and paper industry and formerly in the manufacture of chlorine and caustic soda (chlor-alkali process) and was subsequently discharged to the water. Due to a number of documented episodes of serious mercury toxicity, government actions led to the substitution of mercury in these processes. Reductions in industrial releases of mercury have resulted in a decrease in mercury levels in fish and the restoration of some commercial fisheries in the Great Lakes (walleye in Lake Erie). There are still many advisories on sport fish (e.g., trout and walleye) as a result of mercury contamination from industrial and natural sources. Methyl mercury has been cited as the possible cause of a neurological disease in some native communities which consume large amounts of contaminated fish. It is also a neurotoxin and a developmental toxin in animals.

Alkylated Lead

Alkyl lead compounds (e.g., tetraethyl lead) are produced mainly as lead additives for gasoline. Single acute doses of tetraethyl lead are at least 20 times more toxic than equivalent doses of inorganic forms of lead. Levels of alkylated lead in the environment have decreased since 1981 and will continue to decrease as it is phased out of gasoline. The presence of alkyl lead in the terrestrial environment, especially in urban areas, has been associated with adverse effects on children. Its presence in the Great Lakes basin should be carefully assessed. Alkyl lead should not pose any risk to human health, provided fish consumption guidelines are followed. This conclusion is based on data on alkyl lead residues in fish from the two most contaminated rivers (St. Lawrence and St. Clair).

Steering Committee Membership

Mr. Denis A. Davis — Chairperson
Director General
Inland Waters Directorate
Environment Canada

Mr. J. Roy Hickman
Director General
Environmental Health Directorate
Health and Welfare Canada

Mr. Geoff L. Holland
Director General
Physical and Chemical Sciences Directorate
Department of Fisheries and Oceans

Working Group Membership

Dr. David Peakall — Chairperson
Canadian Wildlife Service
Environment Canada

Dr. Rod Allan
National Water Research Institute
Environment Canada

Mr. Vic Cairns
Great Lakes Laboratory for Fisheries and Aquatic Sciences
Department of Fisheries and Oceans

Dr. John Cooley
Great Lakes Laboratory for Fisheries and Aquatic Sciences
Department of Fisheries and Oceans

Mr. Glen Fox
Canadian Wildlife Service
Environment Canada

Dr. Andy Gilman
Environmental Health Directorate
Health and Welfare Canada

Mr. Darrell Piekarz
Great Lakes Environment Office
Environment Canada

Dr. Jay van Oostdam
Environmental Health Directorate
Health and Welfare Canada

Dr. David Villeneuve
Environmental Health Directorate
Health and Welfare Canada

Mr. Mike Whittle
Great Lakes Laboratory for Fisheries and Aquatic Sciences
Department of Fisheries and Oceans

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Glossary

Definition of terms as used in this synopsis.

Bioaccumulation

A general term describing a process by which chemical substances are ingested and retained by organisms from the environment directly or through consumption of food containing the chemicals. For a discussion of **biomagnification** please see page 11.

Carcinogen

A substance which induces cancer in a living organism.

Congenital anomalies

Birth defects.

Contaminant

A substance foreign to a natural system or present at unnaturally high concentrations.

Dioxin equivalent

A relative measure of toxicity expressed as enzyme induction in rat liver tissue culture. Dioxin-like chemicals (e.g., PCBs, furans) are compared to the most toxic dioxin congener (2,3,7,8-TCDD).

Effluent

A complex waste material (e.g., industrial liquid stream or municipal sewage) which is discharged into the environment.

Embryotoxicity

Adverse toxic effects of chemical agents on the developing embryo.

Epidemiology

The study of the prevalence and spread of disease in a community.

Indicator species

A species that can provide an integrated measure of environmental changes. In this report, species are selected that accurately reflect contaminant levels in their environment or because they give "early warnings" of adverse health effects.

Long range atmospheric transport

The movement of chemical substances present locally to a remote location often over a number of days or weeks via the atmosphere.

Organochlorine

A complex organic molecule with chlorine atoms attached. These chlorinated organic chemicals (e.g., organochlorine pesticides) are manufactured but can also be produced in combustion or formed in waste disposal sites.

Organohalogen

A complex organic molecule with atoms of fluorine, chlorine, bromine and/or iodine attached. These chemicals are commercially manufactured but can also be produced in combustion or formed in waste disposal sites.

Persistent toxic substance

Any toxic substance that is difficult to destroy or that degrades slowly, i.e., with a half-life in water greater than eight weeks.

Reproductive success

The proportion of reproductive attempts which produce healthy, independent young.

Resuspension

The remixing of sediment particles and pollutants back into the water by storms, currents, organisms and human activities such as dredging.

Teratogen

An agent that increases the incidence of congenital malformations (birth defects).

Toxic substance

A substance that can cause death, disease, birth defects, behavioural abnormalities, genetic mutations or physiological or reproductive impairment in any organism or its offspring or that can become poisonous after concentrating in the food web or in combination with other substances.

Toxicology

The study of the adverse effects of chemical agents on biological systems.

Canada

Environment Canada Environnement Canada

Environment Canada
Communications Directorate
Ontario Region
25 St. Clair Avenue East, 6th Floor
Toronto, Ontario
M4T 1M2

Fisheries and Oceans Pêches et Océans

Fisheries and Oceans Canada
Communications Directorate
Bayfield Institute
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario
L7R 4A6

Health and Welfare Canada Santé et Bien-être social Canada

Health and Welfare Canada
Publications Distribution Centre
19th Floor
Jeanne Mance Building
Tunney's Pasture
Ottawa, Ontario
K1A 0K9

Government of Canada | Gouvernment du Canada

TOWARD A HEALTHY GREAT LAKES – ST. LAWRENCE ECOSYSTEM

CLEAN WATERS

This brochure is produced to help you understand some of the problems facing the Great Lakes - St. Lawrence ecosystem, especially pollution by toxic substances. It also explains what is being done, particularly by the Canadian Government, to clean up and restore this ecosystem to a healthy state.

We focus mainly on the Great Lakes. But the lakes and rivers are linked and need to be seen as an ecosystem in which air, water, wildlife, people and pollution move readily.

This publication refers largely to work of the Canadian Government but also to that of other governments in Canada and the United States. Readers are urged to contact Canadian and other government agencies, businesses and non-government groups for more detailed information.

A list of contacts is found at the end of this brochure.

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THE GREAT LAKES – ST. LAWRENCE
A DAMAGED ECOSYSTEM

"... to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin ecosystem."

— from the 1978 Canada - United States Great Lakes Water Quality Agreement.

THE GREAT LAKES - ST. LAWRENCE basin is one of the greatest fresh water systems in the world.

The lakes are so vast that early explorers called them Sweetwater Seas. They hold nearly one-fifth of the fresh water flowing on the Earth's surface.

Their headwaters begin in the middle of the continent and flow as far as 3,800 kilometres to the Atlantic Ocean in a voyage that can take two centuries. On that journey they shape the lives and futures of eight million Canadians.

You and I are part of the journey of those waters as we are part of the ecosystem. We draw water into our homes where we drink it, cook with it and bathe in it. Then we drain it back into the lakes, through vast sewer systems and treatment plants. The water reaches us in other ways. It evaporates into the sky to fall as rain on our forests and food crops and provides moisture in the air we breathe.

This ecosystem that supports our life has been polluted by years of careless human development.

Now a success story, Lake Erie was said to be dying from pollution, during the 1960s and 1970s. In fact, it was becoming excessively alive as phosphorus pollution form sewage, detergents and phosphate fertilizers accelerated the growth of green algae. When algae dies the waters become low in oxygen choking out other forms of life, including some fish.

Concentrated efforts by Canada and the United States to reduce phosphorus inputs through improved sewage treatment and banning phosphates in laundry detergents reversed the problem. Today Lake Erie supports a vibrant commercial sport fishery.

Today we are finding that chemical pollution in the Great Lakes can be directly linked to massive reproductive failures in wildlife, particularly in fish-eating birds such as eagles, gulls and cormorants. In a series of rescue missions over the last 30 years we have attacked one form of pollution after another, building and improving sewage treatment plants and banning or limiting the use of many toxic chemicals. But the battle against pollution is not over. Some fish are unsafe to eat and some wildlife is still born with deformities or has trouble reproducing.

Chemical pollution is still finding its way into the Great Lakes. Part of it comes from our industries. Some of it comes from our own households. Many of us empty chemical containers or wash paint brushes in sinks. We also spray chemicals onto our lawns and gardens. These residues are washed into creeks and storm sewers that drain to the lakes.

If we intend to clean up the Great Lakes and restore a healthy ecosystem we will have to adjust to lifestyles and business practices that allow both a healthy environment and a healthy economy. It is a way of living that a growing number of people call sustainable development. ■

POLLUTION SOURCES AND ECOSYSTEM HEALTH

WATER POLLUTION CAN COME FROM many unexpected sources including long-range air pollution from industrial smokestacks and incinerators, as well as some pesticide sprays picked up by the winds and carried across continents. Studies by Environment Canada estimate that several tonnes of airborne pollutants rain down on the Great Lakes basin each year.

Large amounts of hazardous chemicals wash off the land. Sources include improper or inadequate sewer systems, cars, our pets, our farms and land that has been contaminated by careless storage of hazardous materials.

Great Lakes pollution is also caused by spills, emptying tonnes of harmful material into the lakes. In 1988 the Ontario government's Spills Action Centre reported over 300 spills of oils, chemicals, wastes and other contaminants into the Great Lakes and tributaries. The U.S. Coast Guard reported an average of more than 500 spills a year on its side of the lakes during the 1980s.

IMPLICATIONS FOR ECOSYSTEM HEALTH, INCLUDING HUMANS

Several of the chemicals found in the ecosystem have been linked with reproductive and developmental problems in wildlife.

People often believe that cancer is the biggest hazard from toxic chemicals. Great Lakes scientists say that there may be a greater risk from the effects of chemicals on the nervous system, fertility, the development of young and reduced immunity to disease.

Studies show that sixteen Great Lakes - St. Lawrence wildlife species have suffered reproductive problems or declines in populations since the 1950s. They include 10 fish-eating bird species, the beluga whale, mink and otter, lake trout, sauger and snapping turtle. In each case, high levels of at least one chemical were found in the animals, their eggs or offspring.

In past decades the Great Lakes herring gulls and double-crested cormorants were among the most contaminated birds in the world. Both species, particularly the cormorants, suffered major reproductive failure and there were deformities in some birds that did hatch. Laws instituted in the 60s and 70s caused most pollution levels to drop in recent years and the populations of fish-eating birds are rebounding. There are still deformities in some hatchlings in highly-polluted parts of Saginaw Bay in Lake Huron and Green Bay in Lake Michigan.

Some species, such as mink living along shorelines of Lake Ontario, and lake trout from Lakes Ontario and Michigan appear to have difficulty reproducing in their natural habitat. Studies suggest this is linked to PCBs in their environment.

Turtles from parts of the lower Great Lakes and the St. Lawrence River have accumulated levels of PCBs and related chemicals and they also have high numbers of dead or deformed embryos. The

CHANGING THE ECOSYSTEM

The ecosystem has been altered not only by pollution but by tampering with the physical structure of the lakes and by the introduction of exotic species.

- Many of the marshes that marked the boundary between river and lake have been cleared to make room for harbors and marinas, eliminating breeding grounds and habitat for fish, birds and many animals.
- The sea lamprey, an eel-like creature, has attacked the lake trout, whitefish, chub, lake herring, cisco and burbot from the lakes during the 1930s and 1940s. Chemical treatment has kept the lampreys in check but has not eliminated them. So far control measures have cost over $100 million with no end in sight.
- The zebra mussel, which blankets hard surfaces like rocks and pipes, was first found in Lake St. Clair in 1987 and quickly spread throughout the Great Lakes. This striped mollusc will likely be accidentally carried to inland waters. The thumbnail-sized shellfish probably hitched a ride into the lakes in ballast water that a freighter picked up in Europe and discharged here. Already the mussels have clogged water intake pipes in Lake Erie and threaten to smother the spawning grounds of fish and compete with other lake dwellers for floating algae in the lakes.
- Other fish species have been introduced to the lakes, such as the alewife and species of salmon, competing with native fish for food and habitat.

THE INTERNATIONAL JOINT COMMISSION (IJC)

The International Joint Commission, a six-member body appointed by the Canadian Prime Minister and the President of the United States to advise the two nations on boundary water issues, reports regularly on the state of the lakes.

They have positively identified 362 pollutants that have been found at times in the water, sediments, fish, animals and waterfowl — 32 metals, 68 pesticides and 262 organic chemicals, including industrial substances and waste byproducts. Eleven of the 362 have been singled out by the IJC as critical or priority pollutants because they are persistent and can accumulate in fish, harm fish and wildlife or can threaten human health.

The IJC has identified 42 Areas of Concern for special attention and cleanup. Seventeen of these are in Ontario, including five in the boundary rivers that connect the Great Lakes and are shared with the United States.

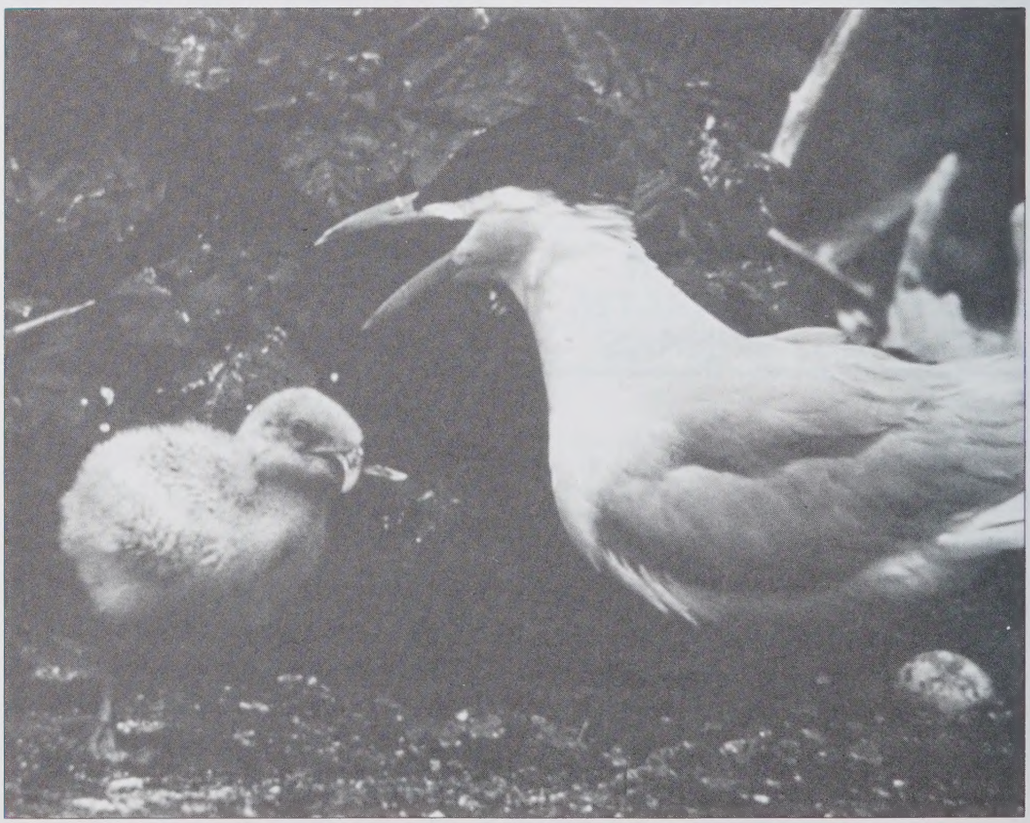
small, white beluga whales of the St. Lawrence estuary, already an endangered species because of overhunting in years past, now appear to be dying off. Their bodies carry some of the highest pollution levels of any animal on the continent.

Human tissue studies have found that many of the toxic chemicals found in the ecosystem also turn up in our bodies. However, the human samples taken so far have found that most people living around the Great Lakes basin do not have higher levels of pollutants in them than people in other industrialized parts of North America. Further studies are planned to get a clearer picture of chemical contaminants in our bodies.

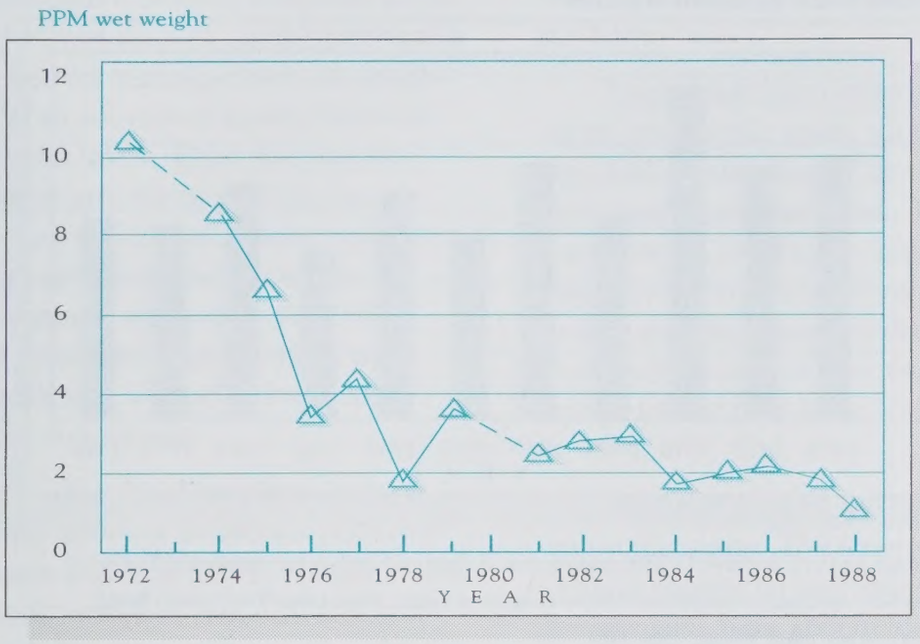
We know of at least one group of people who have been affected by higher than normal levels of pollution. The people studied regularly ate contaminated fish from Lake Michigan. The children of mothers who ate an average of 6.7 kilograms (15 pounds) of contaminated fish a year from Lake Michigan were born smaller than average. At age four the children had poorer memories than normal youngsters, based on psychological testing.

This research appears to confirm evidence in wildlife that links exposure to some contaminants in the environment to harmful health effects.

The risks from pollution in the Great Lakes food chain are not new. Contamination by mercury and hazardous chemicals like PCBs, mirex and dioxins have forced periodic closures of some commercial fisheries or warnings against eating sport fish in each of the Great Lakes, Lake St. Clair and the connecting rivers for two decades. In recent years, the



Lake Ontario
Credit River
PCBs



PCB concentrations in lean dorsal muscle tissue of Coho Salmon collected from the Credit River, Lake Ontario. SOURCE: Ontario Ministry of the Environment & Ontario Ministry of Natural Resources, 1987 (unpublished data)

number of restrictions has declined in some areas, but health experts say that people should adhere to guidelines for sport fish consumption published by governments. Commercial fish must meet government safety standards before being sold.

Over the years there has also been a heated debate about the safety of drinking water from various parts of the lakes. Studies of treated tap water around the lakes have found contaminants to be within maximum acceptable guidelines. But the fact that dozens of chemicals and metals may be in the water has caused great concern among citizens and sparked an ongoing debate as to how to reduce their levels.

Although the definitive studies on the health effects on humans of toxic chemicals in the lakes have yet to be done, senior advisors are issuing strong warnings that we need to do a better job of cleaning up in order to reduce risks.

The Great Lakes Science Advisory Board to the International Joint Commission said in 1989 that: "it is reasonable to presume that toxic chemical exposures are adversely affecting human health. The effects may not be life-threatening at a personal level, but may have a significant effect on the health of our children." This statement was reinforced in 1990 when the IJC commissioners said that even the relatively low levels of toxic chemicals in the Great Lakes ecosystem can pose a threat to the health of children. They called for "every available action" to eliminate the flow of toxic substances into the Great Lakes. ■

ELEVEN CRITICAL POLLUTANTS IN THE GREAT LAKES

— from the list of the Great Lakes Water Quality Board of the International Joint Commission.

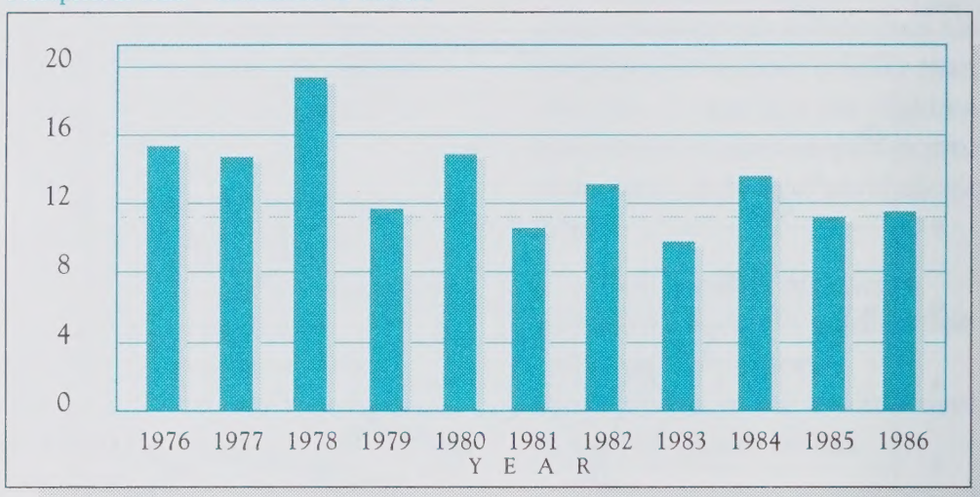
- PCBs (industrial chemicals used in electrical and hydraulic equipment)
- DDT and its breakdown products (pesticide)
- dieldrin (pesticide)
- toxaphene (pesticide)
- dioxin (2,3,7,8-TCDD) (combustion byproduct)
- furan (2,3,7,8-TCDF) (combustion byproduct)
- mirex (pesticide, industrial chemical)
- mercury (industrial metal)
- benzo(a)pyrene (B(a)P) (combustion byproduct)
- hexachlorobenzene (pesticide and combustion byproduct)
- alkylated lead (gasoline additive)

WHAT HAS BEEN DONE ABOUT THE POLLUTION

"...boundary waters and water flowing across the boundary shall not be polluted on either side to the injury of health or property on the other side."

— from the 1909 Boundary Waters Treaty between Canada and the United States.

Lake Erie - Total Phosphorus Loading



The target load for Lake Erie is 11,000 tonnes per year. Annual loads are based on estimates of the total of atmospheric, industrial, municipal and tributary phosphorus inputs. Great Lakes Water Quality Board Report on Great Lakes Water Quality, 1987.

POLLUTION PROBLEMS ARE OLD ENOUGH and serious enough to have been part of a treaty signed more than 80 years ago. That treaty presaged today's concern that pollution respects no boundaries. Since then, Canada and the United States have signed a series of agreements aimed at restoring the lakes to good health.

The 1972 Great Lakes Water Quality Agreement, the first major pact, dealt mainly with phosphorus controls and sewage treatment to stop the accelerated eutrophication or "ageing" of Lake Erie and Lake Ontario.

Based upon joint scientific studies of the late 1960s, Canada and the United States agreed to reduce phosphorus inputs by setting a schedule of reduction targets to be achieved over a period of five years. At a combined cost of 13 billion dollars spent over the last twenty years building new sewage treatment plants and improving existing facilities, the two Parties reached those targets. Experts now confirm that Lakes Erie and Ontario are no longer suffering from too much phosphorus.

In 1978 the Great Lakes Water Quality Agreement was revised to address the contamination of the lakes by toxic persistent chemicals. The renewed agreement called for the protection of the Great Lakes Basin Ecosystem expanding the protection of Great Lakes water quality to include the need to care for the air, land and all living things around the lakes. Recognizing the insidious nature of toxic chemical contamination, the Parties adopted the philosophy of zero discharge and virtual elimination for the control of toxic persistent substances, in spite of scientific uncertanties regarding the measurement of minute concentrations and the long-term effects of these substances in the environment and human health.

The research surveillance and control activities carried out under the 1978 Agreement recognize the full extent of toxic chemical pollution and sources, underscoring the need for a comprehensive attack on all sources of toxic chemicals to the lakes. Over the past few years environmental groups, academic organizations and the government have conducted extensive reviews of the 1978 Agreement. These results were added as a detailed Protocol to the Agreement.

The 1987 revisions include new annexes to address pollution from airborne toxics, contaminated sediments and groundwater and pollution from urban and agricultural run-off. The Protocol includes a commitment to develop Remedial Action Plans to clean up 42 severely polluted sites around the Great Lakes. In addition, the Parties agreed to develop ecosystem health objectives to ensure restoration of the entire basin ecosystem as opposed to the restoration of only the waters of the lakes.

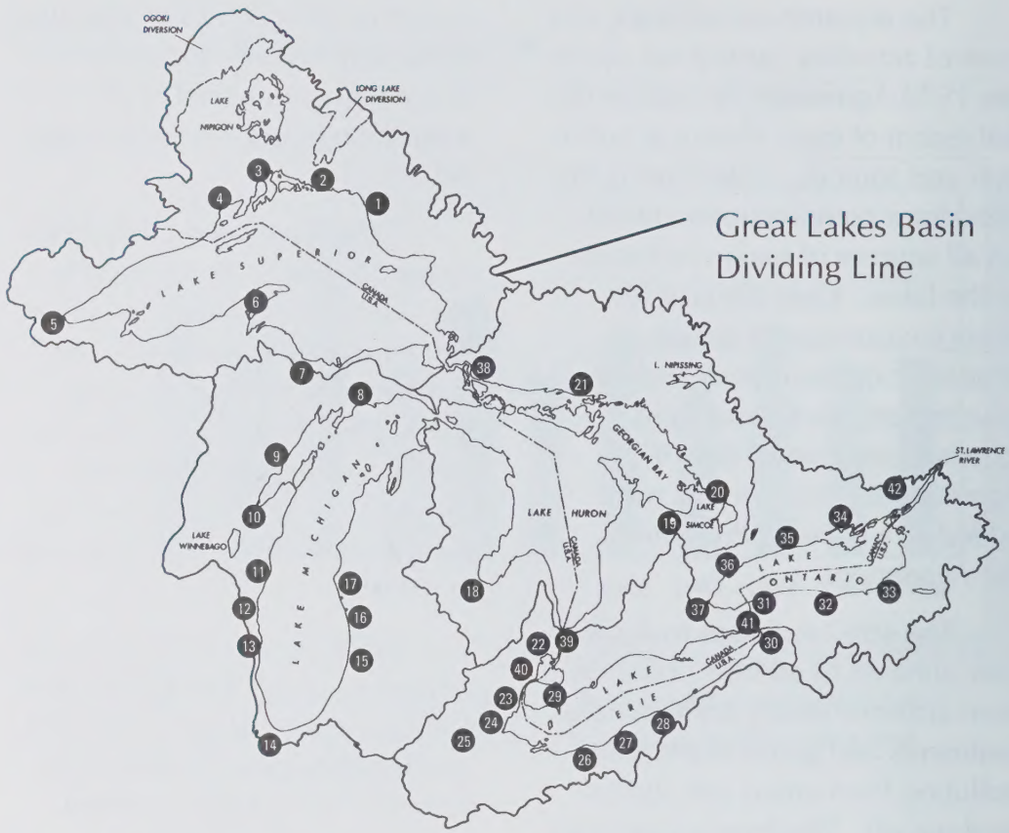
There have been other agreements on specific areas, such as the 1987 Declaration of Intent on Pollution of Niagara River. This committed Canada, the United States, Ontario and New York, to reduce specific chemical discharges from sewers and leaking dumps to that river by at least half by 1996.

Pollution control has not been without its costs. The federal and Ontario provincial and municipal governments have spent close to $3 billion on sewage treatment systems over the last 20 years. Some experts say that when you add spending by local governments you could double the figure. ■

"The 1978 amendments to the Great Lakes Water Quality Agreement state as their purpose, restoration of the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem. Reactive measures — regulations on discharges from existing sources, and concerted efforts to clean up hazardous waste sites — are central in efforts to achieve this goal. But, in the long run, reactive measures are not enough. The Science Advisory Board in its 1987 biennial report stressed the importance of anticipatory, preventive and adaptive strategies to assure ecosystem health within the Great Lakes basin. The Board highlighted sustainable development as a desirable goal towards which anticipatory and preventive strategies can be aimed."

— from the 1989 report of The Science Advisory Board to the International Joint Commission.

GREAT LAKES AREAS OF CONCERN



LAKE SUPERIOR
(1) Peninsula Harbour
(2) Jackfish Bay
(3) Nipigon Bay
(4) Thunder Bay
(5) St. Louis River
(6) Torch Lake
(7) Deer Lake-Carp Creek-Carp River

LAKE MICHIGAN
(8) Manistique River
(9) Menominee River
(10) Fox River/Southern Green Bay
(11) Sheboygan
(12) Milwaukee Estuary
(13) Waukegan Harbor
(14) Grand Calumet River/Indiana Harbor Canal
(15) Kalamazoo River
(16) Muskegon Lake
(17) White Lake

LAKE HURON
(18) Saginaw River/Saginaw Bay
(19) Collingwood Harbour
(20) Penetang Bay to Sturgeon Bay
(21) Spanish River Mouth

LAKE ERIE
(22) Clinton River
(23) Rouge River
(24) Raisin River
(25) Maumee River
(26) Black River
(27) Cuyahoga River
(28) Ashtabula River
(29) Wheatley Harbour

LAKE ONTARIO
(30) Buffalo River
(31) Eighteen Mile Creek
(32) Rochester Embayment
(33) Oswego River
(34) Bay of Quinte
(35) Port Hope Harbour
(36) Toronto Waterfront
(37) Hamilton Harbour

CONNECTING CHANNELS
(38) St. Marys River
(39) St. Clair River
(40) Detroit River
(41) Niagara River
(42) St. Lawrence River

REMEDIAL ACTION PLANS

In 1985 Canada and Ontario agreed to a new approach to remediate severely degraded sites around the Great Lakes by developing Remedial Action Plans for each site. There are 17 RAPs in Canada, 12 of them in Ontario alone and five conducted jointly with the United States on the rivers that connect the lakes. RAPs bring governments, businesses, environment groups and individual citizens to the table to agree on how to restore polluted areas in their regions to a healthy state. The aim is to focus local public attention on examining the problems and finding solutions based on their vision of what kind of future they want for their waters.

- RAPs are led by teams of government technical experts, who can explain the pollution problems, the health implications and the feasibility of different cleanup options.

- Public advisory committees or stakeholders are established to advise these teams. There are nearly 400 Canadians involved in public advisory committees and about 6,000 people who are keeping in touch with the RAP process.

- In some areas the pollution straddles borders. The federal, provincial and state governments are working together to develop cleanup plans along with business people and citizens.

- Responsiblity for specific cleanup measures is determined. Those responsible are expected to commit to a schedule and expenditure which becomes part of the plan.

- Cleanup plans, with commitments and schedules, are to be finished for Ontario's 17 problem areas by 1993. These cleanups will cost hundreds of millions of dollars in total. We will all need to have a voice in the decisions about the choices ahead.

- Plans are submitted to the IJC where the progress and implementation are monitored. ■

THE FEDERAL ROLE

Agriculture Canada
Environment Canada
Fisheries and Oceans Canada
Health and Welfare Canada
Public Works Canada
Transport Canada

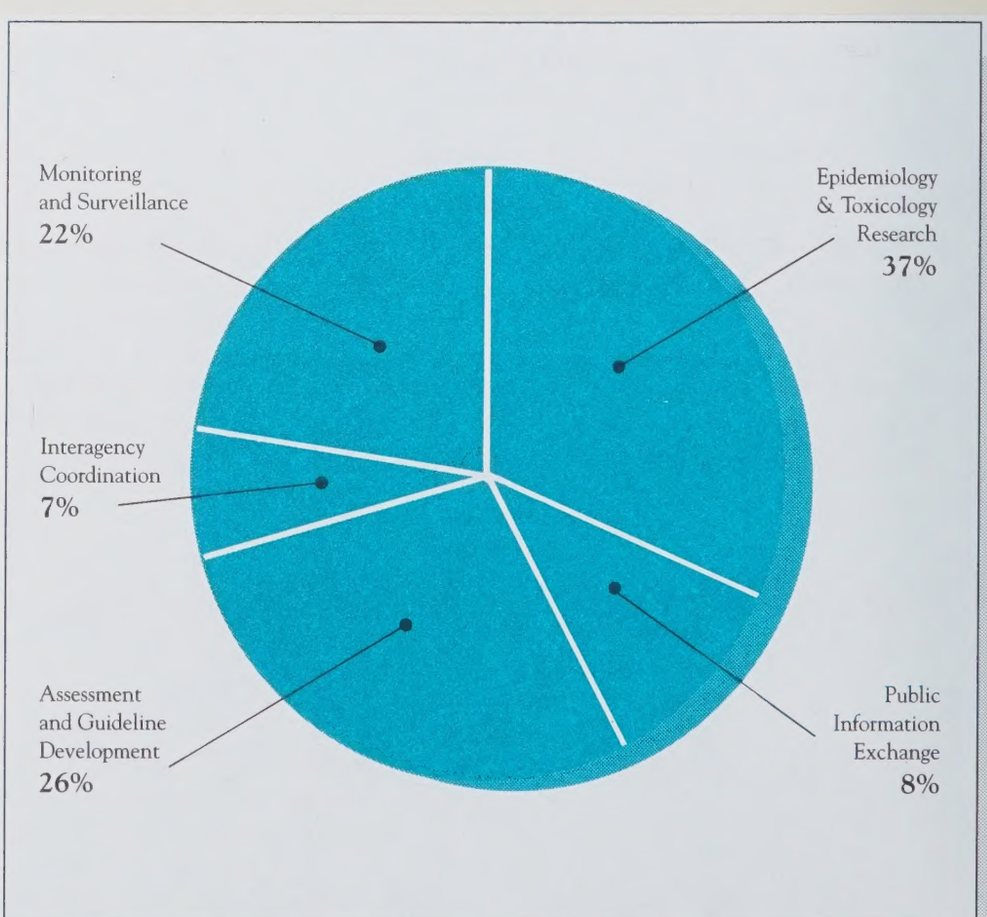
THE FEDERAL GOVERNMENT'S ROLE IN the Great Lakes - St. Lawrence cleanup is to provide overall leadership and co-ordination for the actions being taken by governments, businesses and citizens in Canada. This role also involves co-ordinated actions with the United States. The Canadian government has the responsibility for funding cleanups on federal property and for conducting and funding much of the research needed to implement a cleanup program.

There are six federal departments with responsibilities for protecting the Great Lakes: Environment Canada, Fisheries and Oceans Canada, Health and Welfare Canada, Transport Canada (Canadian Coast Guard), Agriculture Canada and Public Works Canada (dredging).

The work of the departments includes basic scientific research on the ecosystem, identifying pollutants and people at risk from pollution, passing and enforcing pollution laws and regulations, restoring and protecting wildlife habitat, regulating pesticides, working with farmers to reduce pollution and inspecting ships to avoid spills.

Federal Resources - Great Lakes Action Plan

Human Health Effects Program



THE GREAT LAKES ACTION PLAN

In 1989 the federal government announced it would spend a further $125 million over five years under the Great Lakes Action Plan. The money will help clean up and maintain water quality as well as prevent future pollution of the lakes. Elements of the plan include:

- **$55 Million Great Lakes Cleanup Fund**

Established in 1990, this fund is providing money to ensure the clean up of pollution sources within federal jurisdiction in the 17 Canadian Areas of Concern. These initiatives include: addressing the problem of contaminated sediments in federal harbors; dealing with historic wastes on federally-controlled lands; and, testing new cleanup techniques and technologies in programs with other government departments and the private sector. Managed by the Great Lakes Environment Office of Environment Canada, cleanup projects will be funded from late 1990 through to 1995. Environment Canada is the first agency to dedicate a specific fund to ensure that federal remedial measures in Areas of Concern can be started.

- **$50 Million for a Great Lakes Preservation Program**

This program brings together the scientific and technological expertise of the federal departments of Environment, Fisheries and Oceans, Agriculture, Transport and Public Works to address Great Lakes pollution. This includes such activities as research into the behaviour of contaminants mixed in water sediments and how they impact plant and fish life. Such knowledge is essential in order to decide how to deal with contaminated sediments in many of our industrialized harbors around the lakes.

Due to the large surface area of the lakes, the atmospheric deposition of toxic chemicals remains a problem. Canadian and American experts on air emissions, atmospheric chemistry and the measurement of wet and dry deposition of toxics are working together to establish and operate an integrated monitoring network around the Great Lakes. This network will provide measurements of the amount of toxics falling directly into the lakes.

Experts are also working to improve the ability to prevent and respond to spills from shipping accidents, not only to protect human life but to protect wildlife and their habitat.

The Preservation Program expands the fundamental scientific activities underlying water quality management to ensure the protection of the Great Lakes. This expansion is evident in the establishment of the Great Lakes University Research Fund. The four million dollar fund was established by agreement between Environment Canada and the Natural Sciences and Engineering Research Council specifically to engage the expertise of the university research community in direct support of Great Lakes water quality management needs.

HISTORICAL OVERVIEW

- 1909 Boundary Waters Treaty between Canada and the United States pledged both countries not to pollute boundary waters to detriment of the other side.
- 1955 Great Lakes Fishery Convention, which led to formation of Great Lakes Fishery Commission.
- 1972 Great Lakes Water Quality Agreement dealt mainly with phosphorus control to stop Lake Erie from "dying" of eutrophication.
- 1978 Great Lakes Water Quality Agreement introduced to ecosystem approach and the principle of zero discharge of toxic substances to the lakes.
- 1986 Canada-Ontario Agreement Respecting Great Lakes Water Quality co-ordinates federal and provincial actions to clean up the Great Lakes.
- 1986 Toxic Substances Control Agreement on the ecosystem among the eight Great Lakes states, Ontario and Quebec.
- 1987 Declaration of Intent on Pollution of Niagara River committed the governments of Canada, United States, Ontario and New York, to reduce certain toxic discharges to the river by at least half by 1996.
- 1987 Protocol to the 1978 Great Lakes Water Quality Agreement covered the development of Remedial Action Plans and such issues as toxic chemical deposition, leaking dumps and polluted runoff.
- 1988 St. Lawrence Action Plan announced by federal government to protect, conserve and restore the river's water quality.
- 1989 Great Lakes Action Plan announced by federal government to clean up and prevent future pollution of the lakes and to address existing and future health risks.

THE GREAT LAKES ACTION PLAN (cont'd)

- **$20 million for a Human Health Effects Program**

The Department of National Health and Welfare is consulting extensively with Great Lakes communities and undertaking studies to get a better handle on the effects of toxic chemicals in the Great Lakes ecosystem on human health. The aim is to identify those populations most at risk and to find ways to protect them from pollution. Researchers will test people for chemical levels over a period of time and check for health problems that might be related to pollution. In particular they will be looking at the health of people who eat greater than average amounts of fish or other foods from the lakes. Researchers are particularly interested in the health of children, who are more vulnerable to many pollutants than are adults. People considered to be at risk will be advised on how they can reduce their exposure to pollution.

CANADIAN ENVIRONMENTAL PROTECTION ACT

The Canadian Environmental Protection Act (CEPA) has given the federal government stronger powers to control the use of hazardous substances throughout their life cycle. It is now being used to control the handling and discharge of a number of toxic substances, such as PCBs, dioxins and furans. The program screens new chemicals for safety before they are allowed onto the market. It also reviews existing chemicals to see if they pose a threat to the environment and should be more tightly controlled.

FEDERAL PULP AND PAPER REGULATIONS

In 1990 the Federal Environment Minister announced a program that would require pulp and paper mills, including those on the Great Lakes - St. Lawrence system, to sharply lower their pollution discharges. New regulations under CEPA and the Fisheries Act will control the release of a wide range of harmful substances to the environment and virtually eliminate the release of dioxins and furans. They will require that the effluent of all mills be not acutely lethal to fish. Mills will have to be in compliance with the new standards by 1994.

THE ENVIRONMENTAL PARTNERS FUND

This five-year, $50 million program, announced in June, 1989, pays for up to 50 per cent of an environmental project to a maximum federal contribution of $200,000 over three years. It is aimed at groups wanting help in community-oriented environmental projects. Part of the money for this national program will be available for projects in the Great Lakes.

ST. LAWRENCE ACTION PLAN

The St. Lawrence River has long been heavily polluted, both by chemicals draining from the Great Lakes and from pollution added by cities, industries and farms in Quebec.

This great river is also the drinking water source for three million people and at times the water has been so polluted by raw sewage that there was a risk of infection.

The 1,200-kilometre-long river and its bottom muds are heavily laden with chemicals and it still has high levels of fresh human and animal wastes. In a major construction program, Quebec is building $6.2 billion of sewage treatment plants along the St. Lawrence and its tributaries. It has also created a St. Lawrence River cleanup plan to make business development along the river environmentally acceptable, helping to restore the river to a healthy state.

In 1988 the federal government announced a $110 million St. Lawrence Action Plan over five years to help reduce industrial pollution. The main objective is to reduce by 90 per cent the toxic liquid discharges into the river from the 50 industrial sites considered to be the biggest polluters. Another important goal is to protect 5,000 hectares (50 square kilometres) of vital wildlife habitat, especially wetlands, along the river.

Some of the money will also be used in the cleanup of federal properties, the protection of endangered species, the development of environmental technologies, studies of St. Lawrence ecosystems, and the creation of a national marine park at the confluence of the Saguenay and St. Lawrence rivers to protect the area and the marine populations, especially the beluga whales.

The federal pollution control work involves work by the federal departments of Environment, Fisheries and Oceans, and Industry, Science and Technology. It involves collaboration with similar work being done by the Quebec government. As part of the action plan, the federal government created the St. Lawrence Centre.

CANADIAN COAST GUARD

Foreign organisms are transported into the Great Lakes in ballast water that ships pick up in one part of the world and dump in the lakes before they take on cargo. In order to prevent such unwanted invasions, the Canadian Coast Guard has voluntary guidelines asking all ships destined for the St. Lawrence Seaway and the Great Lakes to exchange ballast water at sea or in the St. Lawrence River. More than 1,000 sea-going ships enter the lakes each year. Some expert groups have said that it will require stronger controls to prevent ships from continuing the old practice of dumping water in the lakes. In 1990 Transport Canada began a program to monitor compliance with the guidelines to see if any changes are needed.

OTHER GOVERNMENTS

Much of the cleanup work around the lakes is the responsibility of Ontario and Quebec, the United States and the eight Great Lakes states bordering the basin.

Some projects are operated jointly. Agriculture Canada and the Ontario Ministry of Agriculture and Food are co-operating in the Soil and Water Environmental Enhancement Program (SWEEP). It helps farmers use agricultural techniques that reduce soil erosion in the Lake Erie basin. This will cut the amount of soil flowing into the lake, protecting agricultural lands for future generations and reducing the amount of fertilizers and pesticides that are carried into the lakes.

PROVINCIAL CONTROLS

Environment Ontario is bringing in one of the strictest water pollution control plans in Canada. The Municipal Industrial Strategy for Abatement (MISA) requires virtually zero discharge of persistent toxic substances into the province's waterways. MISA will regulate about 12,000 industries in the province as well as all municipal sewage discharges.

Ontario is also preparing a Clean Air Plan that will require the reduction of air pollutants that now fall on our waters.

The province's Food Systems 2002 program is aimed at helping growers reduce their use of pesticides by half and this will cut the amount of pesticides that can drain into waterways and the lakes. Ontario estimates this program will save farmers more than $100 million in chemical costs.

SHARING RESPONSIBILITIES

The U.S. federal government, particularly the Environmental Protection Agency (EPA) and the eight Great Lakes state governments have spent large amounts of money on Great Lakes cleanups. The EPA office responsible for the Great Lakes has spent $11 billion since 1972 and William Reilly, Administrator of the EPA, has said the Great Lakes area is one of the agency's top priorities.

The federal and state governments are using a series of laws to identify the sources of toxic discharges to the lakes to reduce those discharges. As in Canada, the federal and state governments are part of the process of developing Remedial Action Plans to clean up degraded areas.

INDUSTRIAL RESPONSES

Our waters will never be cleaned up without a major effort by industries. Until a few years ago most business leaders gave no indication that they felt a great need to change the long-standing practice of diluting wastes in water. Today the approach is changing and corporate leaders are now talking about major reductions or elimination of pollutants.

Since 1985, Dow Chemical Canada Inc. has spent millions of dollars to begin to disconnect its plants from the rivers and virtually eliminate further discharges to the Great Lakes - St. Lawrence system. Dow has cut the amount of 43 priority pollutants escaping from its Sarnia plants to the St. Clair River from 350 kilograms a day to about five kilograms a day. Much of this was done by finding ways of preventing chemical leakage into the river.

In May, 1990, Dow separated the chemical cycle of its plant at Varennes, just east of Montreal, from the St. Lawrence River and is recycling water used in the factory. Dow is now working to separate its Sarnia chemical operations from the St. Clair River by the year 2000 or earlier in order to virtually eliminate the current emissions. ■

WHAT HAS TO BE DONE IN THE FUTURE

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

- Our Common Future, The World Commission on Environment and Development, 1987

THE TERM "SUSTAINABLE DEVELOPMENT" was popularized by the 1987 report of the World Commission on Environment and Development, the Brundtland Commission. It defines sustainable development as that which, "meets needs of the present without compromising the ability of future generations to meet their own needs."

It is a good phrase but difficult to practice, because eliminating or reducing our worst environmental impacts means making big changes in the way we live and do business. In the case of the Great Lakes and St. Lawrence this means restoring a seriously damaged ecosystem created by years of carelessness and neglect. This means finding ways of eliminating the discharge of toxic wastes.

We have a major effort ahead of us to identify populations that have been exposed to too much pollution and to help reduce their exposures. We must act now, working together for self protection, environmental preservation and cleanup.

We must learn to plan our activities in a way that anticipates and prevents problems rather than just treating and trying to cure them afterwards. We have to decide what kind of ecosystem we want for ourselves and our children. Do we want to be able to swim virtually anywhere, to eat fish and drink the water without worrying about impacts on our health? We must decide how clean our ecosystem should be. What future do we see for other species?

To a certain degree nature will cleanse the waters after we stop adding more pollution. If we stop polluting, sedimentation, evaporation, flushing and dilution will eventually reduce the severity of local toxic hotspots, bury pollution on the bottom of the lakes with fresh mud or flush chemicals into the Atlantic Ocean. But this will not happen overnight. It can take 190 years for water to move out of Lake Superior alone and another 30 years to reach the ocean. While this action will reduce chemicals in the lakes and rivers, it will spread them further into the world.

We must understand that sewage treatment plants are not equipped to deal with toxic chemicals and most of what goes down the drain will return to the lakes and eventually find its way into our food, air and drinking water.

Industries must install closed loop processes that do not release toxic substances. We must improve farming and land development practices to prevent pesticides from washing off the land. We must do a better job of making, handling and storing hazardous materials that now keep leaking into the waters.

Every citizen must realize that any waste that goes down the drain or into garbage will sooner or later pollute the environment. We have to become better environmental guardians and the best way to do this is to replace dangerous household chemicals with safe ones — consumer action!

To move towards a sustainable society we will have to make significant changes in the way we produce energy, use cars, farm produce, handle oil and chemicals and manage our forests. We will have to develop towns and cities in ways that reduce the daily discharge of wastes into the waters.

We must control the release of air pollution in Canada and work on international agreements to control pollution that travels from other nations. A number of environment-economy experts say this will require rich nations like Canada to subsidize pollution controls in developing nations in our common interest.

All these and other actions will help us reach a sustainable society. We have to participate in the debate and in actions. We can get more information and provide our ideas through the Remedial Action Plans, the federal Green Plan and the sustainable development strategies of Round Tables on Environment and Economy at the national and provincial levels. ■

"The Governments of the United States and Canada clearly recognized the increasing importance of human health issues and their relation to ecosystemic health issues in the 1987 revisions to the Great Lakes Water Quality Agreement of 1978. The Board considers that the issues identified in the 1987 amendments have major implications for human and ecosystemic health and that there is a clear need for a comprehensive binational investigation, not limited to the Great Lakes basin, to address questions concerning the relationship between toxic ecosystems, people's exposure to toxic chemicals and health."

- from the 1989 Great Lakes Science Advisory Board Report to the International Joint Commission.

TO RESTORE AND PROTECT: *WHAT YOU CAN DO TO SAVE THE ECOSYSTEM*

As citizens of the world, we who live around the Great Lakes - St. Lawrence ecosystem have a responsibility to restore and protect one of the great sources of fresh water for the planet. As people who live with the waters we have a duty to protect water quality for ourselves, our children and other species of life. If we are going to have environmentally sustainable lifestyles, we will have to choose techniques, technologies and products that have a lower total impact on our environment.

- We can reduce our use of electricity and heating fuel at home, buy fuel-efficient cars and use cars less often, use fewer toxic chemicals in the home and garden and buy fewer throwaway products.
- By now most Canadians living around the Great Lakes - St. Lawrence ecosystem know about recycling and have a recycling box. This is just the start of a waste reduction, reuse and recycling program. You can speed the process by doing a waste inventory in your home, looking for hazardous products and disposing of them properly.
- You can reduce your demand below the average 300 litres of water, most of which gets quickly flushed down the drain, putting more strain on the water and sewer system.
- You can avoid flushing chemicals down the drain, thus adding a chemical load to somebody's source of drinking water. It is cheaper and safer to keep grease, hair and other solid wastes out of the drains than to pour toxic drain cleaners into the plumbing.
- Reduce or eliminate the use of lawn and garden chemicals that the rains wash into sewers and from there into the lakes. Even the wastes that go into landfill dumps can emerge after rain water seeps through the soil and dissolves hazardous materials.
- Do a better job of recycling at home and at the office. For example, Ontario has a target of 50 per cent recycling of wastes by the year 2000.
- Don't pour old paints and waste chemicals down your sinks or throw batteries and chemicals into the garbage. Get them into hazardous waste pickups by your municipality or the provincial government.

More and more books on how to prevent environmental problems are available from environment groups, governments, businesses and in bookstores. Environment Canada has published, What We Can Do For Our Environment: Hundreds of things to do now.

We can also play a personal role in helping to restore and protect our society. You can be involved in Remedial Action Plans for polluted areas in Ontario. A list of contacts is provided.

You can let people know what you want done to clean up the environment around our waters. Write or phone your elected officials, get your business or business association involved in reducing pollution and recycling. Contact environment groups that are trying to protect the Great Lakes and the rest of our environment.

FOR MORE INFORMATION PLEASE CONTACT

ENVIRONMENT CANADA

Environment Canada provides information on research and plays a key role in negotiations over cleanups involving several parties. It is involved in Remedial Action Plans and the Great Lakes Cleanup Fund.

For information about Great Lakes issues from Environment Canada, contact:

Great Lakes Environment Office
Conservation and Protection Service
Environment Canada, Ontario Region
6th Floor, 25 St. Clair Avenue East
Toronto, Ontario M4T 1M2
Tel (416) 973-8632

Communications Directorate
Environment Canada, Ontario Region
6th Floor, 25 St. Clair Avenue East
Toronto, Ontario M4T 1M2
Tel (416) 973-6467

The Environmental Partners Fund
Environment Canada, Ontario Region
3rd Floor, 25 St. Clair Avenue East
Toronto, Ontario M4T 1M2
Tel (416) 973-1076

THE ST. LAWRENCE ACTION PLAN

This is a program to help clean up the St. Lawrence River and protect environmentally valuable areas.

The St. Lawrence Centre
Environment Canada
105, rue McGill, Bureau 400
Montreal, Quebec H2Y 2E7
Tel (514) 283-7000

REMEDIAL ACTION PLANS

These are plans for the cleanup of polluted Areas of Concern around the Great Lakes.

For information on the RAP plan in general, contact:

Remedial Action Plans
Public Consultation Coordinator
Environment Canada, Ontario Region
6th Floor, 25 St. Clair Avenue East
Toronto, Ontario M4T 1M2
Tel (416) 973-9736

For more information about water quality issues in a specific Area of Concern call the Remedial Action Plan (RAP) coordinator for the area. Collect calls will be accepted.

Metro Toronto Waterfront
Tel (416) 424-3000

Hamilton Harbour
Tel (416) 336-4888

St. Marys River
Tel (Toll free) 1-800-265-0248

St. Clair River
Tel (Toll free) 1-800-265-0248

Detroit River
Tel (Toll free) 1-800-265-0248

Niagara River
Tel (416) 521-7720

St. Lawrence River
Tel (416) 973-9736

Peninsula Harbour
Tel (807) 475-1315

Jackfish Bay
Tel (807) 475-1205

Nipigon Bay
Tel (807) 475-1205

REMEDIAL ACTION PLANS (cont'd)

Thunder Bay
Tel (807) 475-1205

Collingwood Harbour
Tel (416) 323-4956

Severn Sound
Tel (416) 323-4956

Spanish Harbour
Tel (705) 675-4501

Wheatley Harbour
Tel (519) 661-2200

Bay of Quinte
Tel (613) 549-4000

Port Hope Harbour
Tel (416) 973-1060

HEALTH AND WELFARE CANADA

The federal department of Health and Welfare Canada is the lead agency in advising Canadians about risks from pollution and promoting the "healthy community" concepts. It monitors food safety, issues advisories and works with the provinces to develop drinking water guidelines.

For information about health and environment issues in general contact:

Publications Distribution Centre
Health and Welfare Canada
Room 512, Brooke Claxton Building
Tunney's Pasture
Ottawa, Ontario K1A 0K9
Tel (613) 952-9191

For information about the Great Lakes Health Effects Program contact: Health Protection Branch
Health and Welfare Canada
Environmental Health Directorate
Tunney's Pasture
Ottawa, Ontario K1A 0L2
Tel (613) 957-1876

DEPARTMENT OF FISHERIES AND OCEANS

The fisheries department is responsible for protecting fish from pollution and this has a direct bearing on water quality.

Department of Fisheries and Oceans
Communications Directorate
200 Kent Street West, Station 1478
Ottawa, Ontario K1A 0E6
Tel (613) 993-0999

CANADIAN COAST GUARD

The Coast Guard is responsible for safety of commercial vessels and is involved in preventing and cleaning up spills.

Canadian Coast Guard
Transport Canada
Central Region Headquarters
1 Yonge Street, 20th Floor
Toronto, Ontario M5E 1E5
Tel (416) 973-2162

AGRICULTURE CANADA

Agriculture Canada is responsible for regulating pesticides and working on water protection through soil conservation. For information contact:

Agriculture Canada
Sir John Carling Building
930 Carling Avenue
Ottawa, Ontario K1A 0C5
Tel (613) 995-5222

PUBLIC WORKS CANADA

This department has a responsibility in the cleanup of pollution on federal property. This includes using safe dredging techniques to remove contaminated sediments.

Public Works Canada
Place du Portage, Phase IV
140 Promenade du Portage
Ottawa, Ontario K1A 0M3
Tel (613) 997-7525

ONTARIO GOVERNMENT

Every year the Ontario Government publishes the Guide to Eating Ontario Sport Fish, a comprehensive listing of contaminants in sport fish. It lists the levels of mercury and hazardous chemicals in fish tested from hundreds of lakes and rivers around the province, including the Great Lakes. The free guidebook indicates which fish should be eaten in limited quantities or not at all.
It is available from:

The Ontario Government Bookstore
880 Bay Street
Toronto, Ontario M7A 1N8

Public Information Centre
Ontario Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5
Tel. (416) 323-4321

Public Information Centre
Ontario Ministry of Natural Resources
Room 1640, Whitney Block
Toronto, Ontario M7A 1W3
Tel (416) 965-2000

It is also available from most Liquor Control Board Outlets, Brewer's Retail outlets and some fishing licence vendors.

THE INTERNATIONAL JOINT COMMISSION

The International Joint Commission is a binational body that deals with boundary waters between Canada and the United States, especially the Great Lakes.

Information and reports on Great Lakes issues can be obtained from:

International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario N9A 6T3
Tel (519) 256-7821

ENVIRONMENT AND ECONOMY ROUND TABLES

Round Tables have been appointed by the Prime Minister of Canada and Premiers of most provinces to help reach consensus on how to have both a healthy environment and a healthy economy.

The three that deal with the Great Lakes basin are:

National Round Table on the
Environment and the Economy
1 Nicholas Street, Suite 520
Ottawa, Ontario K1N 7B7
Tel (613) 992-7189

Ontario Round Table on Environment and Economy
790 Bay Street
Suite 1003
Toronto, Ontario M7A 1Y7
Tel (416) 327-2032

Quebec Round Table on Environment and Economy
Ministry of Environment
2360 chemin Ste-Foy, 1er étage
Ste-Foy (Québec) G1V 4H2
Tel (418) 646-6590

MUNICIPAL GOVERNMENTS

A growing number of municipalities have environment committees and groups responsible for everything from the planning of waste disposal sites to recycling. Contact your municipal government, including the politicians, public works, waste management and waterworks and health departments for information on what they are doing to protect local water resources.

UNITED STATES

Since pollution often moves across boundaries, actions in the United States often have an impact in Canada.

Great Lakes Fishery Commission
1451 Green Road
Ann Arbor, Michigan 48105 U.S.A.
Tel (313) 662-3209

For information about U.S. Federal pollution controls, contact:

Environmental Protection Agency
Region V
230 South Dearborn Street
Chicago, Illinois 60604 U.S.A

Environmental Protection Agency
Region II
26 Federal Plaza, Room 900
New York, N.Y. 10278 U.S.A.

CITIZEN GROUPS

Non-government groups have often alerted the public to the seriousness of environmental issues and have worked with governments and some businesses to find solutions. They are a valuable source of information on Great Lakes and other environment issues. Some of the groups dealing with Great Lakes - St. Lawrence issues include:

Great Lakes United (binational)
State University College
Cassetty Hall
1300 Elmwood Avenue
Buffalo, N.Y. 14222
Tel (716) 886-0142

Pollution Probe Foundation
12 Madison Avenue
Toronto, Ontario M5R 2S1
Tel (416) 926-1907

Canadian Environmental Law Association
517 College Street, Suite 401
Toronto, Ontario M6G 4A2
Tel (416) 960-2284

Conservation Council of Ontario
489 College Street, Suite 506
Toronto, Ontario M6G 1A5
Tel (416) 969-9637

Greenpeace - Toronto Regional Office
578 Bloor Street West,
Toronto, Ontario M6G 1K1
Tel (416) 538-6470

Great Lakes Tomorrow
720 Bathurst Street, Suite 403
Toronto, Ontario M5S 2R4
Tel (416) 536-9161

The Centre for the Great Lakes
(Toronto office)
320 $^{1}/_{2}$ Bloor Street West, Suite 301
Toronto, Ontario M5S 1W5
Tel (416) 921-7662

Société pour vaincre la pollution
C.P 65, succursale Place d'Armes
Montréal (Québec) H2Y 2T1
Tel (514) 844-5477 ■

READING LISTS

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Science Council of Canada, *Water 2020, Sustainable Use for Water in the 21st Century,* Report 40, Ottawa, 1988.

World Commission on Environment and Development, *Our Common Future* (the Brundtland Report), Oxford, 1987.

For additional copies of this publication contact:

Environment Canada
Communications Directorate, Ontario Region
25 St. Clair Avenue East, 6th Floor
Toronto, Ontario
M4T 1M2
(416) 973-6467

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CLEANING UP OUR GREAT LAKES. A REPORT ON TOXIC
SUBSTANCES IN THE GREAT LAKES BASIN ECOSYSTEM. 1991.

I. E. S.
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1994

INST. FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF TORONTO
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Cleaning up OUR GREAT LAKES

A Report on Toxic Substances in the Great Lakes Basin Ecosystem

Cleaning up our Great Lakes
A Report from
The Water Quality Board to
The International Joint Commission
on Toxic Substances in
The Great Lakes Basin Ecosystem

August, 1991

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Water Quality Board Report Cover Design

The cover centers around a child-like illustration using a primary colour scheme to portray a positive vision of the state of the Great Lakes. The illustration shows the elements in our environment-earth, air and water. The play toys- the pail, shovel and truck left on the beach without the child - signify a child who was once at play. These toys are subtly emphasized and enlarged across the entire background of the cover to create balance and added interest.

The cover's message is that our children have been left with a legacy: As children, they play and enjoy the Great Lakes with a child's tools, but later as adults they will be faced with a major task to improve the quality and condition of our Great Lakes. The positive image of the cover is contrasted by photographs within the report, as they depict the realities and effects of persistent toxic substances on the Great Lakes.

International Joint Commission
Commission mixte internationale

GREAT LAKES WATER QUALITY BOARD

September 1991

International Joint Commission
Canada and United States

Commissioners:

The Water Quality Board hereby submits its 1991 report to the International Joint Commission. The report responds to the priorities statement dated June 7, 1990 and is particularly oriented to the state of knowledge on toxic substances and persistent toxic substances.

Respectfully,

V. V. Adamkus
United States Chair

D. L. Egar
Canadian Chair

THE INTERNATIONAL JOINT COMMISSION

THE INTERNATIONAL JOINT COMMISSION (IJC) IS A PERMANENT, SIX-MEMBER BODY THAT WAS CREATED BY THE UNITED STATES AND GREAT BRITAIN ON BEHALF OF CANADA UNDER THE BOUNDARY WATERS TREATY OF 1909. THREE OF ITS MEMBERS ARE APPOINTED BY THE PRESIDENT OF THE UNITED STATES AND THREE ARE APPOINTED BY THE PRIME MINISTER OF CANADA. THIS COMMISSION, WHICH HAS OFFICES IN WASHINGTON, D.C., OTTAWA AND WINDSOR, ONTARIO, HAS BEEN MEETING SINCE 1912 TO ADVISE THE TWO GOVERNMENTS ON BOUNDARY WATER ISSUES.

The Commission rules on applications for the use, obstruction or diversion of boundary waters between Canada and the United States. It also investigates and advises on boundary water issues jointly referred by the two governments.

Over the past two decades, one of the major tasks of the IJC has been to report regularly on progress in cleaning up the Great Lakes, under the 1972 and 1978 Great Lakes Water Quality Agreements and the 1987 Protocol to the 1978 Agreement.

The Water Quality Board is an 18-member advisory board to the IJC. The Board consists of an equal number of members from Canada and the United States; from the two Federal governments and from the governments of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin, and the provinces of Ontario and Quebec.

ACKNOWLEDGEMENTS

THE WATER QUALITY BOARD EXPRESSES ITS APPRECIATION TO MR. MICHAEL KEATING FOR PREPARING THIS REPORT. HE HAS DRAWN UPON THE WORK DONE BY A NUMBER OF OTHER IJC BOARDS AND EXPERT GROUPS. THESE INCLUDE THE SCIENCE ADVISORY BOARD, VIRTUAL ELIMINATION TASK FORCE, STATE OF GREAT LAKES ECOSYSTEM TASK FORCE AND THE WORK OF A NUMBER OF CONSULTANTS TO THE COMMISSION.

This report also draws on, "Toxic Chemicals in the Great Lakes and Associated Effects," a report by Environment Canada, the Department of Fisheries and Oceans and Health and Welfare Canada, and, "A Prescription for Healthy Great Lakes," by the National Wildlife Federation and the Canadian Institute for Law and Policy.

Preface

The Water Quality Board believes that persistent toxic substances pose the greatest current threat to the Great Lakes ecosystem. The intent of this report is to provide the International Joint Commission, governments, business and the public with a concise report on the state of toxic contamination of the Great Lakes. It outlines the problems that remain, some of the successes that have been achieved, and suggests some options for the future.

Under the direction of the IJC, the Board itself is undergoing a transition and is taking on more of a policy advisory role to the Commission and is reducing its role as an evaluator of government programs. In the future, the IJC will receive assessments of the governments' Great Lakes programs from a variety of advisory groups. These include the Science Advisory Board, IJC staff, special task forces and round tables, and public meetings.

The role of the Board is to provide advice on broad policy questions and priorities for the cleanup and future protection of the Great Lakes. In response to its new mandate, the Board has identified 15 priority issues, which it hopes to address in the coming years. These priorities are spelled out in detail in the concluding pages of this report.

In synopsis, the top priorities are the provision of advise for the next Great Lakes Water Quality Agreement; assessing and managing risk and damage to the ecosystem and dealing with varying regulatory systems. The Board thinks that governments around the lakes need to develop better integrated methods of managing watersheds and shorelines. It also considers there is a need to study the management and preservation of underground water systems in the basin.

Further priorities include a stronger involvement of municipalities, industry, agriculture and forestry in protecting the lakes; evaluation of education and information programs; development of a working definition of sustainable development of the basin; public health; the control of pollution from faraway sources; tourism; fisheries and water diversions.

Members of the Water Quality Board think that we who live around the Great Lakes are at an historic point. After years of experience with pollution, we now have a very good understanding of what must be done to restore a healthy ecosystem. We have the know-how to clean up our lakes, but to do so we now have to make serious decisions. These decisions include the banning of some chemicals, the strengthening of some regulations and the changing of some business practices and lifestyles. Although governments must pass regulations, provide some funding and co-ordinate research, much of the work of cleaning up and protecting the lakes has to be done by businesses and citizens. This means that all of us have to understand the importance of pollution prevention and learn how to practice it in our daily lives.

This is our vision of the Great Lakes of the future. This is what we are striving to achieve.

The Great Lakes watershed is a clean, safe environment where life forms exist in harmony. People take pride in the Great Lakes. We share and live an ethic which recognizes that environmental integrity provides the foundation for a healthy economy.

We are secure in the knowledge that the fish and wildlife are healthy and the water can be enjoyed by all.

We understand our responsibility for ensuring a self-sustaining Great Lakes ecosystem. This is the example we set for the rest of the world and the legacy we leave our children.

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INTRODUCTION

THE GREAT LAKES ARE SO BIG THAT ASTRONAUTS COULD SEE THEM FROM THE MOON. THEIR HEADWATERS BEGIN IN THE MIDDLE OF THE CONTINENT AND FLOW 3,800 KILOMETRES TO THE ATLANTIC OCEAN IN A VOYAGE THAT CAN TAKE TWO CENTURIES. ON THAT JOURNEY THEY SHAPE THE LIVES AND FUTURES OF MORE THAN 37 MILLION PEOPLE.

The five lakes form the largest reservoir of drinkable water on the planet. They contain one-fifth of the fresh water on the earth's surface and 80 per cent of that in North America. Early Jesuit missionaries called the lakes the Sweetwater Seas for in those days one could dip a cup into their waters anywhere and drink deeply and without fear of contamination. Since then, the Great Lakes - St. Lawrence River region has become a magnet for settlement and development. It is an industrial centre for two great nations. And it bears the scars of decades of pollution by everything from raw sewage to complex chemicals. Despite sewage treatment plants, towns and cities ringing the lakes still discharge so much bacteria-laden sewage that the lake water they draw is not safe for drinking without disinfection. Many municipal beaches are too polluted for swimming, mainly because rains overload sewage treatment plants, washing raw sewage into the lakes, and some people still discharge some untreated sewage directly into the waters.

Along the shores of the lakes and their tributary rivers, our society has built about 13,000 factories that refine petroleum and that make plastics, chemicals, paints, iron, steel, cars, pulp and paper and a host of other products. On the fertile plains surrounding the lakes, people have developed large and highly-productive farms, pastures and stockyards. These businesses all have an impact on the environment of our lakes.

THE GREAT LAKES AS VIEWED FROM SPACE

Over the past century we have changed the lakes in many ways. By cutting forests, plowing land, introducing farm animals, damming tributary rivers and dredging or filling river mouths, bays and shoreline marshes, we have changed the shape and quality of many river shorelines. By digging canals we allowed the introduction of foreign organisms such as the sea lamprey and the zebra mussel into the lakes. They entered by swimming or by being carried by ships. We have overfished some native species and introduced others for fishing.

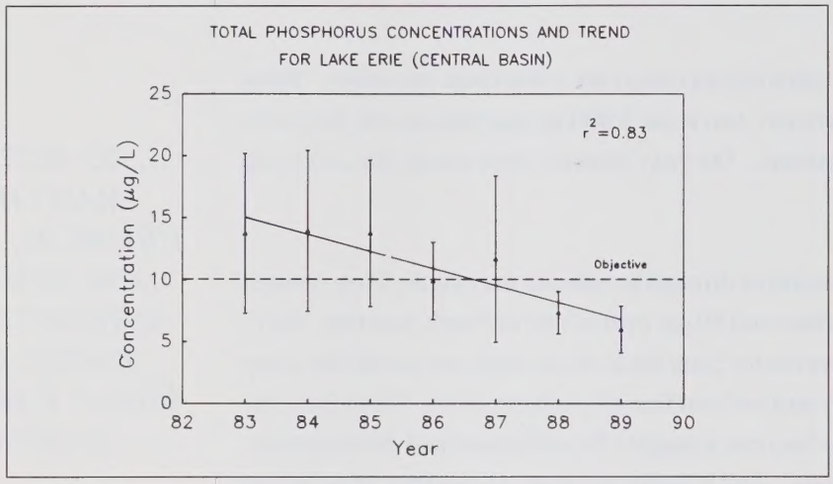
For generations we have used our lakes as a giant sewer, convinced that such vast waters had an infinite capacity to assimilate and neutralize our pollution. The operative phrase was "the solution to pollution is dilution." And we all continue to pollute: big industries, small factories, farms, stockyards and individuals.

....TO RESTORE AND MAINTAIN THE CHEMICAL, PHYSICAL AND BIOLOGICAL INTEGRITY OF THE WATERS OF THE GREAT LAKES BASIN ECOSYSTEM.

- STATEMENT OF PURPOSE FROM THE 1978 CANADA-UNITED STATES GREAT LAKES WATER QUALITY AGREEMENT

To some degree this principle of dilution worked when the quantity of pollution discharged was not too great for the ecosystem to assimilate without damage and the pollutants contained chemicals that nature could easily break down into harmless substances. Over the past three decades we have realized that many wastes do not simply disappear into the lakes. The discharge of thousands of tonnes of phosphorus a year from sewage and from detergents put too great a load on the lakes for them to rapidly assimilate. The phosphorus acted as a fertilizer, causing the development of algae, which drew oxygen out of the water as they decayed. This situation led to such results as dead fish and slimy beaches.

The discharge of persistent toxic chemicals has led to sickness and death among wildlife and the risk of harm to humans. During this century we created chemicals that never existed before and that break down very slowly, if at all, in nature. And we have excavated large amounts of toxic metals from deep in the earth. Persistent toxic substances, including pesticides, transformer fluids, chemical wastes and a number of industrial metals, have penetrated the food chain, killing or injuring wildlife and threatening human health. Some of the chemicals are even passed from one generation to another through the placenta and in mothers' milk.



Multiyear Phosphorus Concentration Trend; Central Basin, Lake Erie

Tens of thousands of chemicals and metals are used around the lakes and hundreds of the more common and persistent ones have been detected in the lakes' ecosystem, including its water, sediments, fish, reptiles, mammals, waterfowl-- and humans. Fish in many areas are too contaminated for human consumption. A number of the birds and animals that feed on contaminated fish have suffered reproductive problems and produced young with birth defects. There is growing evidence that some children have been affected by exposure to toxic chemicals transferred through the placenta and in mothers' milk.

Since the 1960s, public concern about the condition of the lakes has created a political movement both in Canada and the United States that brought pressure for a cleanup of the lakes. This movement has resulted in laws banning or restricting a number of chemicals and in the spending of billions of dollars on sewage treatment. Since the 1970s, there has been a dramatic reduction in the discharges of gross pollution, such as raw sewage and oil. Phosphorus levels have dropped and the algal slime caused by this pollution is receding. The discharge of some hazardous chemicals has been cut significantly.

We still have to reduce toxic chemical discharges, because despite some significant reductions, they are still released by the tonne every day.

- *A number of major industries discharge wastes directly into the lakes.*
- *Some large and many smaller factories discharge their chemical wastes into municipal sewage treatment systems. Some wastes are collected in sewage sludge, while others continue through the sewage system to be discharged into the lakes or tributary rivers.*
- *Old chemical wastes seep into lakes and rivers from buried dumps near the shorelines.*
- *Wastes that have settled on the bottom sediments of industrial rivers and harbors get picked up by wildlife and become part of the food chain.*

- *Oil and chemicals enter the Great Lakes and their tributaries in hundreds of spills a year.*
- *Chemicals from farm fields, lawns and gardens, and pollution from cars, including chemicals, gasoline and oily wastes, wash off the land and into the lakes.*
- *Tonnes of chemicals fall on the Great Lakes watershed every year. They come from industrial smokestacks and incinerators as well as drifting from pesticide sprays. Fallout comes both from local sources and from hundreds, even thousands of kilometres away, before landing.*

Some of the toxic pollution breaks down into less harmful substances and some is buried in the natural process of sedimentation, where it becomes less exposed to the food chain. Part of the chemical load is absorbed by living organisms and gets into the food chain. It is this process that is of greatest concern to people.

Toxic Substances in the Great Lakes

People are concerned about pollutants in the environment that can increase the risk of cancer, birth defects, sterility, mutations and nerve damage, and that attack the nervous system or various organs or can change body chemistry. Once released, certain chemicals build up to ever-higher levels in the food chain, making them more and more dangerous to wildlife and humans.

Scientists have confirmed the finding of 362 contaminants in the Great Lakes ecosystem, including the water, sediments, fish, animals, waterfowl and humans. There are 32 metals, 68 pesticides and 262 other organic chemicals, mainly industrial substances and waste by-products. The list includes 126 substances that can have acute or chronic toxic effects on life.

Eleven of the 362 have been singled out by the Water Quality Board as critical or priority pollutants that have been found to accumulate in fish, harm fish and wildlife, or possibly threaten human health. There is a number of reasons for highlighting these 11 for special attention. They have been confirmed as serious problem substances, that have caused or are very likely to cause harm. There is also a feeling among some researchers that if these 11 can be successfully controlled, then many other, related chemicals could be controlled by the same measures. In other words, the work done to reduce discharges of one chemical will likely also affect related pollutants in the same waste stream.

The toxic substances cover a wide array of materials. Some of the worst problems are caused by a class of chemicals known as organochlorines. They are often toxic and they resist natural bacterial and chemical breakdown processes in the environment. The organochlorine chemicals include insect and weed killers, industrial materials used in the manufacture of other chemicals, and waste by-products of industry or combustion. Heavy metals, such as mercury and lead, are also toxic and persistent in the environment.

• ***PCBs (polychlorinated biphenyls)*** - This is a family of chemicals with up to 209 possible variations. Some members of this family have chemical structures and biochemical characteristics similar to dioxins and others are neurotoxins. Since the 1930s, PCBs have been used widely in electrical, hydraulic and other equipment. Until the 1970s, they were used in such consumer products as domestic fluorescent lights and carbonless copy paper. PCBs are no longer made or sold in North America, but they are still used in a large amount of older electrical equipment. PCBs periodically escape in spills or when old equipment is junked. They are widely dispersed in the environment, are very persistent and accumulate dramatically in the food chain. They have been linked to health problems, such as embryo mortality and deformities in

Eleven Critical Pollutants in the Great Lakes

from the list of the Great Lakes Water Quality Board of the International Joint Commission

PCBs
(industrial chemicals)
DDT
and its
breakdown products
(pesticide)
DIELDRIN
(pesticide)
TOXAPHENE
(pesticide)
DIOXIN
(2,3,7,8-TCDD)
(waste by product)
FURAN
(2,3,7,8-TCDF)
(waste by product)
MIREX
(pesticide, industrial chemical)
MERCURY
(industrial metal)
BENZO(A)PYRENE
(B[a]P)
(waste by product)
HEXACHLOROBENZENE
(pesticide, by product)
ALKYLATED LEAD
(industrial compound used as gasoline additive, being phased out)

wildlife, and are suspected of causing developmental problems in human infants.

• ***DDT and its breakdown products, particularly DDE*** - The insecticide DDT was first widely used after the Second World War, but has been highly restricted in Canada and the United States for two decades, and is now banned. DDT disrupts the body's chemical system of hormones and enzymes. It causes eggshell thinning in a number of fish-eating birds and is associated with the mortality of embryos and sterility in wildlife, especially in birds. In recent years it has been associated with the feminization of embryos. DDT still enters the Great Lakes, probably from a combination of sources. These include long-range airborne transport from countries where it is used, leakage from dumps and may include the illegal use of old stocks.

• ***Dieldrin and the related pesticide, aldrin*** - These persistent chemicals were used mainly as insecticides, starting in 1948. Both are manufactured chemicals, but aldrin is also naturally degraded to dieldrin in the environment. Dieldrin has been linked to the death of adult bald eagles in the Great Lakes basin. Dieldrin levels in herring gull eggs and fish in several areas sampled in the Great Lakes have not declined since the mid-1970s. Dieldrin is still used for termite control.

• ***Toxaphene*** - This chemical, once the most heavily-used insecticide in the United States, was applied extensively to cotton crops in the southeastern United States. Large amounts of it blew north to land on the Great Lakes, building up to substantial levels in fish in Lake Superior. The chemical has been detected in wildlife as far north as the Arctic. The use of toxaphene is now restricted in the United States and there are minimal registrations in Canada.

• ***Dioxin*** - This is a family of 75 chlorinated chemicals, which vary greatly in toxicity. The 2,3,7,8-TCDD variant is considered the most toxic synthetic chemical known. Dioxins are unwanted by-products of combustion and of some industrial processes that use chlorine. The most important source of dioxins in the Great Lakes is the chlorine bleaching of pulp and paper and the production of some herbicides. Dioxins also come from a wide variety of other sources, including incinerators. Dioxins, especially 2,3,7,8-TCDD, are highly toxic to many animals in low doses and are believed responsible for the fatal chick edema disease in Lake Ontario herring gulls in the 1970s. The effects on humans are not well understood, but dioxins are considered very hazardous chemicals.

• ***Furan*** - This family of chlorinated chemicals has 135 variations. Furans are waste by-products both of the manufacture of chlorophenol chemicals and of the same processes that produce dioxin. The 2,3,7,8-TCDF variant is similar to TCDD dioxin, but about one-quarter as toxic. Furans are often found as contaminants in PCBs.

• ***Polynuclear Aromatic Hydrocarbons, (PAHs)***, especially the variant, benzo(a)pyrene (B[a]P) - The PAHs are a waste by-product of the incomplete combustion of fossil fuels and wood, incineration, steel and coke production, and coal liquification and gasification. B[a]P is linked with cancer in wildlife and humans. In the case of humans, this link has been through inhalation at workplaces. PAHs have also been associated with cancers in fish in highly contaminated areas around steel works.

• ***Hexachlorobenzene*** - This chemical was used as a fungicide for cereal crops and it is also a contaminant or by-product of the making of some other pesticides. HCB is persistent and is found in the tissues of fish, animals and humans

from the Great Lakes basin. It interferes with enzymes that control the production of hemoglobin, a constituent of blood. In tests, HCB affects the nerves and causes liver damage, reproductive effects and cancer in laboratory animals. Excessive hexachlorobenzene doses have caused death among infants. Limited uses of HCB are still permitted.

• ***Mirex*** - An extremely persistent chemical that was used as an insecticide and a fire retardant. It has been used extensively as a fire ant killer in the southern United States. It was once packaged along the Niagara River and the shore of Lake Ontario and is found almost exclusively in that lake and downstream into the St. Lawrence River. In laboratory animals, mirex causes reproductive problems and cancer.

• ***Mercury*** - An industrial metal that was used to prevent slime from forming in industrial equipment, and was used in the manufacture of chlorine and caustic soda. Mercury is still used in consumer products, including some street lamps, paints, batteries and light switches. It is also released as a vapor by the burning of fuels containing traces of mercury, particularly in coal-fired power plants. Mercury can build up in the brain, kidney and liver and it harms the nervous system. A number of fishery closures around the lakes were caused by mercury pollution. Mercury residues in fish are still a problem in parts of the Great Lakes, particularly the Lake St. Clair area.

• ***Lead*** - Alkyl lead, particularly tetraethyl lead, was used for decades to increase the performance of gasoline. Alkylated lead is now being phased out of this use in the United States and Canada, but ordinary lead is still used in other applications, such as automotive batteries. Like mercury, lead is a neurotoxin. Studies indicate that the ingestion of lead can reduce intelligence in children and this evidence has been influential in leading to stronger control measures on uses of the metal. The highest alkyl lead concentrations in the Great Lakes are found near where it was processed: at Sarnia on the St. Clair River and at Maitland on the St. Lawrence River. Lead has also been found in atmospheric fallout across the lakes.

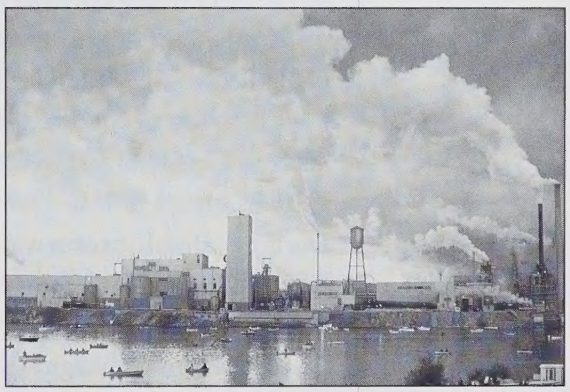
Sources of Pollution

Direct industrial discharges

Large industries have made important reductions in their discharges of toxic substances, particularly over the past 20 years, but they still release significant amounts of hazardous pollutants. There is no comprehensive estimate of the amount of persistent toxic material that is discharged into the Great Lakes every year.

MAJOR SECTORS THAT DISCHARGE PERSISTENT TOXIC SUBSTANCES INCLUDE:

- ***Pulp and paper mills,*** which release tonnes of toxic chemicals into the lakes every day. They have been identified as a major source of dioxins, furans and other toxic organochlorine chemicals. There are 73 mills on the shorelines of the Great Lakes, the upper St. Lawrence and a number of tributary rivers. An Ontario report indicated that, in that province alone, nine mills discharge 200 tonnes a day of chlorinated organic materials. A U.S. report identified nine mills in that country that discharge large amounts of similar materials.



GM Corp., Bay City Plant site contaminated by tonnes of PCBs, adjacent to Saginaw River, Michigan.

- ***Chemical plants,*** which add large amounts of toxic chemicals as a result of leakage and spills from factories, waste discharges through sewer pipes and leakage from old waste dumps. Major chemical industry centres are at Sarnia, Ont. and Niagara Falls, N.Y.

- ***Petroleum refineries,*** that discharge oil, grease, phenols, metals and other toxic substances. There is leakage of old oil spills in some cases. There are 14 refineries discharging into the Great Lakes. Many are concentrated at Sarnia, the Oakville-Mississauga area, Whiting, Indiana and northern Ohio.

- ***Iron and steel mills,*** that release heavy metals, arsenic, phenols, ammonia, other chemicals and PAHs. Major mills are located in Welland, Hamilton, Nanticoke and Sault Ste. Marie, in Ontario, in Detroit, Michigan and in East Chicago, Gary and Burns Harbor, Indiana.

OTHER SIGNIFICANT INDUSTRIAL DISCHARGERS OF PERSISTENT TOXIC SUBSTANCES INCLUDE:

- ***Automotive plants,*** that release metals and organic chemicals from current manufacturing processes and that introduce leakage from old dumps. They also release volatile organic compounds into the air, many as a result of degreasing and painting.

• ***Wood preserving factories,*** that release toxic chemicals and metals used to stop rot in wood.

• ***Metal processing and finishing plants,*** that release acids and toxic metals into the lakes or into municipal sewer systems, that later discharge materials into the lakes.

Municipal sewers with household and industrial discharges

Municipal sewage systems release a significant amount of toxic wastes. The IJC Water Quality Board estimated in 1989 that more than 2,900 tonnes of selected toxic metals and chemicals were released annually by the 1,199 sewage treatment plants around the lakes. This figure included 1,880 tonnes discharged into the water, with the rest going into the atmosphere or into sludge, which is then put in dumps or spread on land. Chemicals in the sludge can reach the lakes through surface runoff or leaching through underground water. If contaminated sludge is used on crops, some of the pollution can enter the food chain. The pollutants listed in the IJC report include arsenic, cyanide, lead, mercury, chloroform, PCBs and phenol. An estimated 300 kilograms a year of PCBs come out of Great Lakes' sewage systems; 73 kilograms of that amount comes from the huge Detroit sewage treatment plant alone.

Pollution comes from thousands of small industries which discharge hazardous chemicals into municipal sewer systems, and from homes. For example, many people use toxic household cleaners and empty chemical containers or rinse paint down the drain.

Many sewage systems are vulnerable to rainstorms. Rain can send a huge amount of water down the storm sewers, which collect street runoff. In cases where storm sewers are combined with the sanitary sewer system that takes waste from buildings, rain can contribute large amounts of water to the relatively smaller normal flows of sanitary sewage wastes. Rain also reaches sanitary sewers by illegal cross connections between the storm and sanitary sewage systems, direct inflow from gutters and yard or factory drains, and infiltration from the soil. During a rainfall, excess water, which is sometimes mixed with raw sewage, will be discharged untreated if the sewage system cannot handle the increased flow, or it will be bypassed to avoid flooding the sewage treatment plants. Around the Great Lakes, there are tens of thousands of pipes where raw sewage is discharged untreated, either during wet weather or even during dry weather in some cases, where the capacity of the sewer pipes is too small for even regular loads.

Leaking municipal and industrial dumps

Millions of tonnes of hazardous wastes have been dumped into pits around the shores of the Great Lakes over the past century. Some of that material has been leaking into the lakes for years and is predicted to continue leaking for decades, even centuries, unless it is stopped. The wastes find their way into underground waters and from there are carried into the lakes. Chemical wastes have been seen running down the face of the Niagara Gorge, near one leaking dump.

One of the best-documented areas for toxic landfills is the Niagara River. An estimated one million tonnes of contaminated material has been dumped in 66 large sites near the river. It is estimated that more than 300 kilograms a day, or about 109 tonnes a year of toxic chemicals seep into the Niagara River from the largest hazardous waste dumps located within five kilometres (three miles) of the shoreline.

Even ordinary municipal dumps contain toxic chemicals that come from small industries and from household wastes, such as old paint, paint removers, oven cleaners, disinfectants, batteries, waste oil, garden sprays and drain cleaners.

Contaminated sediments

The bottoms of many industrialized Great Lakes harbors and the industrialized parts of rivers contain pollution that has drained into those waterways over decades. The worst cases are, in effect, underwater chemical dumps. Contaminated sediments in harbor bottoms are a problem in 42 of the 43 Areas of Concern around the lakes, listed by the IJC.

Pollution from contaminated sediments is absorbed by bottom-dwelling creatures, such as worms, larvae, molluscs and crayfish. From these organisms, contaminants are passed up the food chain into fish, turtles, ducks, eagles, mink, otter and humans. In shallow waters, contaminated sediments are periodically stirred up by wave action, making pollutants more available to fish. Because bottom pollutants can be easily stirred into the water, we are faced with a difficult and costly job. If the pollution is to be safely removed, it must be done in ways that will not release large amounts of it into the water.

Atmospheric fallout

Air pollution is another serious problem for the Great Lakes. It includes chemicals from industries, incinerators and pesticide sprays, that are picked up by the winds and carried across countries to fall on the ground and water. Air pollutants can travel huge distances. Scientists have found that pollution in the Arctic comes from as far away as Europe. One of the most dramatic examples of the long-range transport of pollution came in 1986, when radionuclides from an explosion at the Chernobyl nuclear power plant in the Ukraine circled the earth in 11 days. In North America, researchers found that toxaphene, an insecticide that was widely used on cotton crops in the southeastern United States, had accumulated in fish as far away as Lake Superior. Chemicals, such as DDT, that fall on the Great Lakes are thought to come from at least as far away as Mexico and the Caribbean, where they are still used extensively. These chemicals are sometimes manufactured and exported by companies in the United States. Research also indicates that chemicals may be coming from as far away as Eurasia.

Scientists are trying to calculate the amount of toxic fallout on the lakes. A 1988 study by the IJC estimated that more than four tonnes of PCBs, DDT, Benzo[a]pyrene and lead fall on the Great Lakes basin each year. In the case of Lake Superior, fallout accounted for 90 to 97 per cent of the inputs of these four substances from all sources.

A 1990 IJC study of air pollution around Detroit, Windsor, Sarnia and Port Huron, lists 125 air pollutants, including arsenic, chloroform, formaldehyde and benzene. They include substances that can cause cancer and reproductive problems and can affect the immune, endocrine and nervous systems. The report raised the concern that they could enter the food chain and bioaccumulate. Sources of air pollution in those regions include thousands of large and small businesses, hundreds of thousands of cars and 1,688 incinerators. These incinerators range from small, apartment incinerators to large municipal garbage burners. There is also concern that open burning at landfills is a source of toxic fallout.

Air Quality Monitoring Station, Isle Royale, Lake Superior

Scientists have long felt that a number of persistent, volatile chemicals migrate long distances in a kind of hopscotch from one body of water to another. They evaporate off the surface of the water in sunlight, fall in the rain or snow and are evaporated again. Some chemicals are deposited on land, where they may become part of crops and animal fodder.

Runoff from towns and cities

Pollution, including toxic chemicals from towns, cities and farms, runs off the land and into the lakes, carried along by rainwater and melting snow. It comes from deliberate dumping and accidental spills. A considerable amount comes from cars, including oil, gasoline, antifreeze, windshield washer fluids and by-products of combustion. Some of the chemicals that we spread and spray onto our lawns and gardens are carried by rain water and garden watering into underground water, sewers or creeks that drain into the lakes.

Runoff from farms

Pesticide runoff from farm fields adds weed and insect-killing chemicals to the water. A preliminary study in 1986 found that 30,000 tonnes of pesticides were used in Ontario, Ohio and Wisconsin alone. A significant amount of chemicals sprayed on fields is washed into the lakes in runoff from rain and the spring snow melt. Chemicals also percolate down into the ground water and can slowly work their way into the lakes. Agricultural runoff also includes fertilizers, animal wastes and wastes from processing plants.

Spills from land and ships

Another pollution source is spills, which put many tonnes of harmful materials into the lakes. In 1988, the Canadian Coast Guard verified 195 spills into the lakes, and there were emergency cleanups for two of the oil spills in that list. The same year, the U.S. Coast Guard reported 262 verified spills, 13 of them involving hazardous materials and most of the rest involving oil. There were 17 cleanups for the 262 spills.

The spills vary greatly in size, but chemical spills have been serious enough to cause a number of temporary closings of downstream drinking water intakes, particularly along the St. Clair River. A report to the IJC in 1987 stated that one spill put 80 tonnes of the industrial chemical, styrene, into the St. Clair River. That spill put as much styrene into the St. Clair River as would be allowed in the normal industrial discharge over 1,428 years. Another spill put the equivalent of 58 years of permitted discharges into the river. In May, 1991, a tanker ran aground in Georgian Bay, spilling about 162,000 litres (42,800 U.S. gallons) of gasoline and diesel fuel.

Illegal dumping

A number of businesses still discharge their wastes without treatment and without getting caught. People who illegally pour wastes down sewers or into ditches are sometimes known as "midnight dumpers" because of the time when they engage in such activities. Because of its secretive nature, this means of discharge is impossible to quantify. Governments are using waste tracking reports, called manifests, in an effort to limit the illegal transport and dumping of toxic wastes.

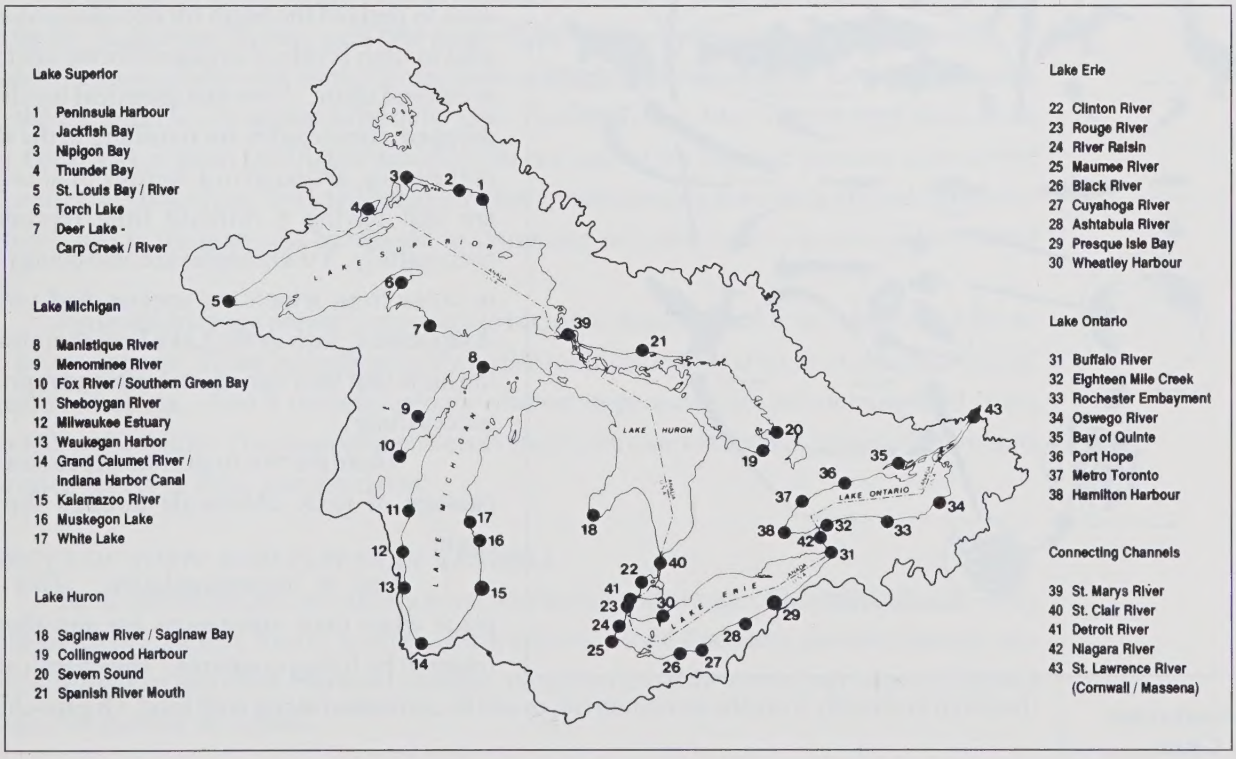
Polluted Areas

The most frequently-cited list of pollution hotspots in the Great Lakes is the one produced by the International Joint Commission. It lists 43 seriously-polluted areas for special attention and cleanup. Officially these are known as Areas of Concern and they have been identified by governments. They are mainly industrial harbors and bays or industrialized stretches of rivers. They include all four rivers connecting the Great Lakes: the St. Marys, St. Clair, Detroit and Niagara, as well as part of the upper St. Lawrence River.

Of these 43 areas, there are 42 which are contaminated by toxic chemicals, and 38 have restrictions on the human consumption of fish. These hotspots include areas on all five Great Lakes, the four connecting rivers and part of the St. Lawrence River. Fish tumours have been identified in 17 of the areas. Only one Area of Concern, Severn Sound in Georgian Bay, does not have toxic chemical pollution. It suffers from phosphate pollution, which degrades water quality to the point that aquatic life can be harmed. In addition to the 43 Areas of Concern, there are many other areas of contamination. Several years ago, an independent analysis listed several hundred sources of contamination. These included industries and municipal sewage treatment plants that discharged high levels of pollution, and hazardous waste sites that could leach chemicals into the lakes and tributary rivers.

The official list of polluted areas will keep changing.

Under rules approved in the 1987 Protocol to the Canada-United States Great Lakes Water Quality Agreement, there is a process to add or delete Areas of Concern.



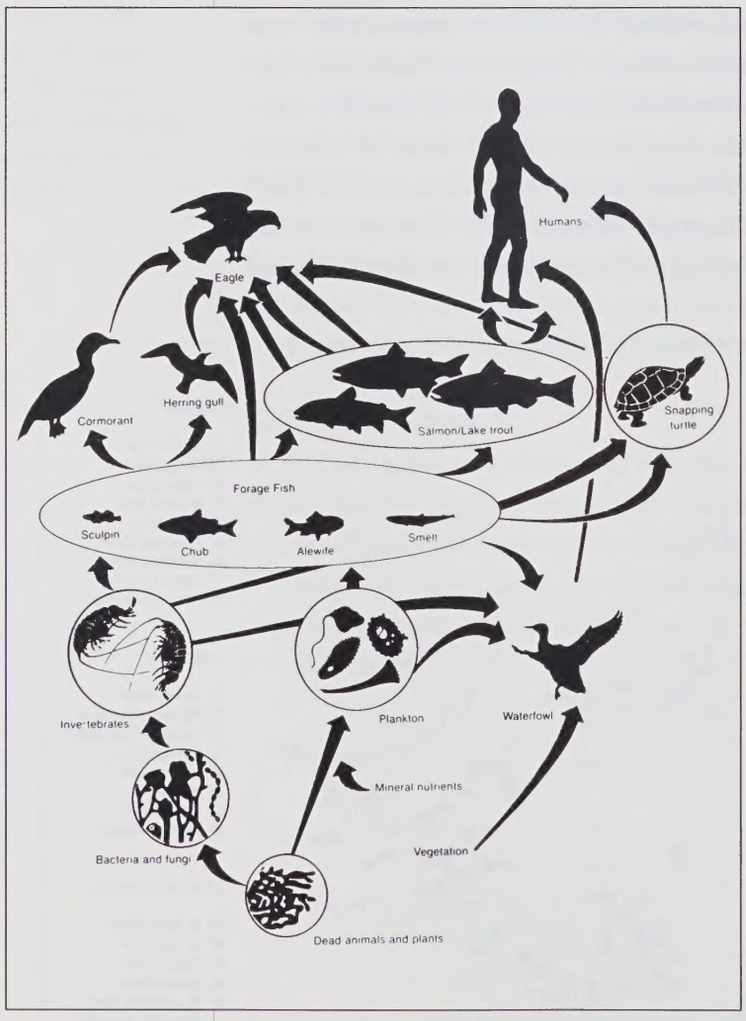
The 43 Areas of Concern in the Great Lakes Basin

Exposure to and effects of Toxic Substances

How wildlife and humans are exposed to toxic substances

We are all part of the food chain-- microscopic plankton, tiny crustaceans, big fish, gulls, eagles, mink, turtles and humans. Thus, we are all exposed to substances that collect in our food, particularly the chemicals that are retained in fatty cells and are passed from one creature to another.

In the Great Lakes food web, chemicals typically enter the base of the food chain at the level of the plankton, where the pollution begins to be concentrated at a low level. As the plankton are eaten by small fish, that are in turn eaten by ever-larger fish, the packages of chemicals in each body are added together. At the top of the food chain, in the bodies of lake trout and fish-eating birds, such as gulls, cormorants and eagles, the levels of contamination get very high. The top predator in the lakes is the bald eagle, which eats fish-eating birds, such as gulls and cormorants. Failure of the bald eagle to reproduce in parts of the basin for decades was attributed to high levels of organochlorine chemicals in its food chain. Now that chemical levels have dropped, some eagles are returning to the shores of the lakes, although in a number of areas, they are still having a difficult time reproducing successfully. Young eagles are also being placed in areas from which the species had virtually disappeared, such as the Lake Erie shorelines, in the hope that they can reestablish and reproduce successfully.



Simplified representation of the Food Chain

There are two important processes in the passage of toxic chemicals through the food chain.

One is bioaccumulation. This takes place when toxic substances are absorbed and retained by living creatures. The chemicals can be taken in directly from the environment, or can be consumed along with food. Organochlorine

chemicals are highly soluble in fat so they accumulate in fatty cells and remain in living organisms.

The second process is biomagnification. This is the process of passing chemicals up the food chain. Each predator on the chain accumulates the chemical load of all the creatures it has eaten. A dramatic example of biomagnification is found in some Great Lakes bird eggs. The level of PCBs in the eggs of bald eagles nesting along the shores of Lake Erie has been measured at up to 25 million times higher than the level in the surrounding lake water.

The movement of toxic chemicals through the food chain can also cover long distances. Researchers have found mirex, a contaminant peculiar to Lake Ontario, in eels that migrate several hundred kilometres down the St. Lawrence River. The eels are eaten by beluga whales in the St. Lawrence estuary and the belugas are contaminated with mirex.

Human exposure

After the discovery of toxic contaminants in the Great Lakes, particularly during the 1980s, there were concerns about their effects on humans. A major study on toxic contaminants in the Great Lakes, released by the Canadian government in March, 1991, said the levels of contaminants in Great Lakes residents in general do not appear to be different from those in people living in other industrialized parts of the continent. However, further studies of chemicals in Great Lakes residents are being undertaken.

Studies of treated tap water from municipalities around the lakes have found that contaminant levels are usually within acceptable guidelines set by federal, state or provincial governments. The most frequent contaminants in the average glass of tap water come from the water treatment and delivery systems, not the lakes. One common pollutant is a family of chemicals called trihalomethanes, which are created during the purification of drinking water with chlorine. Another pollutant found in some water systems is lead, which leaches from lead pipes or lead solder that holds copper pipes together. Trihalomethane levels can be reduced by modifying the way water is treated. Lead exposure can be reduced by running taps for at least a minute if water has been standing in pipes overnight.

Great Lakes residents are exposed to toxic chemicals in different ways. One study, done by Dr. Katherine Davies, said that most of the average person's intake of a number of persistent organic chemicals likely comes from commercially-purchased food. Even in the food, the chemical levels appear to be quite low. That study and other similar ones done in the lower Great Lakes basin calculated that 80 to 90 per cent of the average person's exposure to the chemicals is from food, with the balance of the uptake coming from air and drinking water. The food used in the tests was purchased in stores and included locally-grown and imported items.

While the average person's exposure to toxic chemicals seems to be relatively modest, there are exceptions. These include people who use toxic chemicals at work or at home without adequate protection. And it includes people who eat large quantities of contaminated Great Lakes fish and wildlife. They expose themselves and, in the case of mothers, expose their infants to elevated levels of toxic contaminants.

Effects of toxic substances in general

Toxic chemicals and metals are known to have a wide range of harmful effects. They include mortality, cancer, loss of fertility, birth defects, blood disorders, genetic damage, sex changes, hormonal and other chemical changes, disturbances in the central nervous system and damage to a number of organs.

Effects on wildlife

Toxic chemical effects on Great Lakes wildlife include: cancer, death, eggshell thinning, population declines, reduced hatching success, abnormal behavior such as abandonment of nests, infertility, birth defects such as crossed beaks and club feet, and illnesses such as chick edema. They also include less visible effects on body chemistry, including abnormalities in the thyroid, liver and endocrine systems. According to researchers, there is strong evidence that a variety of diseases in some Great Lakes fish and wildlife is linked to such persistent toxic substances as DDT, dieldrin, PCBs and dioxins.

Since the 1950s, 14 Great Lakes wildlife species near the top of the food chain have suffered reproductive problems, population declines or other physiological problems. They include: mink, otter, double-crested cormorant, black-crowned night heron, bald eagle, herring gull, ring-billed gull, Caspian tern, common tern, Forster's tern, snapping turtle, lake trout, brown bullhead and white sucker. There is research that suggests osprey, great blue heron and Virginia rail have also been affected.

Cormorants: A species damaged by persistent toxic substances

One of the most dramatic effects of toxic chemical pollution has been massive reproductive failures in a number of species of fish-eating birds, such as eagles, gulls and cormorants. The evidence started to appear decades ago, but it took modern chemical testing equipment and a lot of ecological detective work for the scope of the damage to become clear in recent years.

Records show that there was no known successful breeding of double-crested cormorants on Lake Ontario between 1954 and 1977. By the early 1960s and 1970s, this breeding failure had spread to Lakes Michigan and Superior. This was traced to eggshell thinning caused when DDT inhibited the enzymes birds used to form the shells. The eggs would break when the parents tried to incubate them. By the 1960s, most bald eagles on the lower Great Lakes were having trouble breeding successfully. DDT was causing eggshell thinning and adults were being killed by dieldrin.

During the same period, herring gulls were starting to suffer reproductive failure in parts of the Great Lakes. In the late 1960s, some fish-eating birds in Lakes Ontario and Michigan were found to be among the most contaminated birds in the world.

Researchers have also found that contaminants in the Great Lakes may be changing the sexual development of some wildlife. They say that when DDT has been injected into gull eggs, it caused the feminization of male embryos. They note that herring gull embryos and newly-hatched chicks collected from Lake Ontario in 1975 and 1976 showed that five of seven males were significantly feminized. This was a period of high pollution by DDT and other organochlorine chemicals, and a period when there was poor reproduction of the gulls.

Other species of Great Lakes wildlife have been affected. Wildlife researchers say there is evidence that mink and otter living along the shorelines of Lake Ontario, and lake trout from Lakes Ontario and Michigan appear to have difficulty reproducing in the wild. Studies suggest this is linked to PCBs in their environment. It is known that ranch mink fed fish contaminated with PCBs and other organochlorine chemicals are unable to produce live kits.

Turtles from parts of the lower Great Lakes, such as Hamilton Harbor and the St. Lawrence River, have high levels of PCBs and related chemicals, and they have high numbers of dead or deformed embryos. There are tumours in some fish from contaminated parts of the lakes, and studies have associated a number of these tumours with pollution in the local

environment. Tests have shown that fish painted with PAHs from a contaminated river bottom developed skin tumours. Fish tumours are more frequent than normal in a number of industrialized areas of the Great Lakes. These include Saginaw Bay in Lake Huron, Green Bay in Lake Michigan, the North Channel of Lake Huron, near Manitoulin Island, Hamilton Harbor, and the Black River in Ohio.

Current situation

As a result of more stringent pollution controls, the levels of toxic substances in the Great Lakes ecosystem have dropped in recent years and the populations of a number of fish-eating bird species are rebounding. In the case of the cormorant, the population is higher than at any time in this century, a condition which shows that the ecosystem has been altered in a way that is advantageous to this species. However, levels of persistent toxic substances, such as DDT, dieldrin and PCBs, are still high enough that it is difficult for top predators, such as the bald eagle, to re-establish healthy populations in many parts of the shorelines of the Great Lakes.

Species	Population decrease	Effects on reproduction	Eggshell thinning	Congenital malformations[1]	Behavioural changes	Biochemical changes	Mortality	Alterations in recruitment
Mink	X	X	NA	NE	NE	NE	X	?
Otter	X		NA	NE	NE	NE	?	?
Double-crested Cormorant	X	X	X	(X)		X	?	?
Black-crowned Night-Heron	X	X	X	X		X	?	?
Bald Eagle	X	X	X	NE		NE	NE	?
Herring Gull		X	X	X	X	X	X	
Ring-billed Gull				X		NE	X	
Caspian Tern		X		X	NE	NE		X
Common Tern		X	X	X		X		
Forster's Tern		X		X	X	X		
Snapping Turtle	NE	X	NA	X	NE	NE	NE	NE
Lake Trout		X	NA			X		
Brown Bullhead			NA			X		
White Sucker			NA	X		X		

X = effects documented NE = not examined
NA = not applicable ? = suspected since population declined

1. Unpublished records of congenital malformations (gross birth defects) exist for the double-crested cormorant, great blue heron and the Virginia rail.

Species of fish and wildlife suffering known effects from contamination in the Great Lakes

Continuing wildlife health effects

Caspian terns - crossed bills and other deformities and embryo mortality
Cormorants - club feet and crossed bills
Bald eagles - still unable to reproduce normally along shorelines of Great Lakes
Herring gull - deformities and abnormal function of thyroid and liver
Common tern - deformities and embryo mortality
Turtles - deformities and embryo mortality
Mink - indications of failure to reproduce normally along Lake Ontario shoreline

Effects on humans

Since the discovery of high mercury levels in many fish from Lake St. Clair and western Lake Erie in 1970, people have been worried about the effects on humans of toxic chemicals in the Great Lakes food chain. Contamination by mercury and hazardous chemicals, such as PCBs, mirex and dioxins, has caused the closure of several commercial fisheries and warnings against eating sport fish in parts of all the Great Lakes, Lake St. Clair and the connecting rivers.

In news reports, the possibility of cancer is the risk most frequently associated with toxic chemicals. But there is growing evidence that some of the toxic chemicals identified in

the Great Lakes ecosystem are likely to affect the nervous system, fertility, the development of young and immunity to disease.

The most detailed investigation into the effects of Great Lakes pollutants on human health suggests that children may be affected. The study compared 242 children of mothers who regularly ate contaminated fish from Lake Michigan with 71 children of mothers who did not eat such fish. The fish-eating mothers had higher than average levels of several chemicals, especially PCBs, in their blood and umbilical cord serum.

The children of mothers who ate an average of 6.7 kilograms (15 pounds) of contaminated fish a year from Lake Michigan were born earlier, weighed less and had smaller head sizes than the children of non fish eaters. The children of fish eaters were also more easily startled, had abnormally weak reflexes and were less able to detect differences in visual images in front of them. At age four, these children had poorer verbal skills and poorer short-term memories than normal youngsters, based on psychological testing. Researchers think the adverse effects were most likely caused by chemicals passed from the mother to the fetus through the placenta.

In their 1990 report to governments, the International Joint Commission stated that there is: *"Abundant evidence of health effects, particularly in the early developmental stages in wildlife populations."*

The report went on to say that: *"When available data on fish, birds, reptiles and small mammals are considered along with this human research, the Commission must conclude that there is a threat to the health of our children emanating from our exposure to persistent toxic substances, even at very low ambient levels."*

It called for *"every available action"* to eliminate the flow of persistent toxic substances into the Great Lakes.

In the meantime, a number of people still eat large amounts of contaminated fish, waterfowl and other Great Lakes wildlife. These high consumers of wild food include sport fishermen and their families and native people. Health experts say the best way to minimize one's risk is to find out what foods have high levels of contamination and avoid eating them. The larger, older, fattier and higher up the food chain a creature is, the more likely that it will be contaminated. If one eats food that might be contaminated, one should discard the fatty flesh, such as the belly on a fish, and avoid eating the fat that comes from the cooked flesh, because organochlorine chemicals concentrate in fat. This technique does not protect against mercury, which distributes more evenly through meat.

In recent years, the number of restrictions on eating Great Lakes fish has declined, but health experts say that people should continue to adhere to guidelines for sports fish consumption, published by governments. One survey found that only about half of the sport anglers surveyed had seen the guidelines. Commercial fish must meet government safety standards before being sold.

WHAT HAS BEEN DONE TO CLEAN UP THE LAKES

THE UNITED STATES AND CANADA HAVE BEEN WRESTLING WITH THE PROBLEM OF GREAT LAKES POLLUTION FOR MOST OF THIS CENTURY. AT FIRST, THE CONCERN WAS OVER HUMAN SEWAGE THAT WAS POLLUTING SOME BOUNDARY RIVERS, BUT OVER THE YEARS THAT CONCERN HAS SPREAD TO COVER PHOSPHORUS DISCHARGES, ESPECIALLY IN LAKES ERIE AND ONTARIO, AND FINALLY TO TOXIC CHEMICALS IN ALL THE LAKES.

In 1909, the United States and Great Britain, on behalf of Canada, signed the Boundary Waters Treaty, an historic agreement to manage shared waters. Under that treaty, the United States and Canada created the International Joint Commission, a permanent panel appointed by the President and Prime Minister to advise the nations on boundary water issues. The six-member body, based in Washington and Ottawa with a Great Lakes office in Windsor, Ont. keeps a close watch on the Great Lakes. It began operations in 1912 and has reported on the state of the waters since 1918.

In recent decades, pollution reached such high levels that the two nations developed a series of pollution control pacts. They signed the first Great Lakes Water Quality Agreement in 1972, mainly to control phosphorus and sewage discharges. The phosphorus pollution was causing serious eutrophication and a buildup of algae in Lake Erie.

Serious efforts to reduce pollution of the Great Lakes began in the 1960s and accelerated around the time of the signing of the 1972 Agreement. These efforts mainly involved controls on pollutants, such as raw sewage, detergents that were causing rivers to foam, and oil so thick that it could burn on the water's surface. The cleanup at that time mainly involved building industrial waste and municipal sewage collection and treatment systems and passing laws to restrict the use and discharge of several harmful substances.

Controls on toxic chemicals began in the late 1960s and, a decade later, some of the worst excesses in the use and disposal of hazardous chemicals were being curtailed. Since then, a number of major discharges of pollution into the waterways have been cut and there has been a reduction in the dumping of raw chemical wastes into leaky pits beside lakes and rivers. There have also been bans and restrictions on the use of a number of toxic substances, such as PCBs, DDT, dieldrin, aldrin, mirex, hexachlorobenzene and mercury.

Some industrial processes that create dioxins, furans and PAHs have also been controlled and others face new restrictions. In fact, these restrictions were not aimed only at protecting the Great Lakes, but were nation-wide. A number of controls that were sometimes referred to as bans are not total because, in some cases, limited uses are allowed. New uses of PCBs were stopped in the late 1970s, but old PCBs are still in use in thousands of pieces of electrical equipment. There are hundreds of PCB spills each year, as well as volatilization into the atmosphere. The sale of old DDT stocks was allowed in Canada until the end of 1990.

"BOUNDARY WATERS AND WATER FLOWING ACROSS THE BOUNDARY SHALL NOT BE POLLUTED ON EITHER SIDE TO THE INJURY OF HEALTH OR PROPERTY ON THE OTHER SIDE."

- FROM THE 1909 BOUNDARY WATERS TREATY BETWEEN CANADA AND THE UNITED STATES

The attack on toxic substances was written into a binational pact, the 1978 Great Lakes Water Quality Agreement. The pact marked a breakthrough in governments' stated goals for pollution control by calling for the virtual elimination of inputs of persistent toxic substances. This Agreement pledged Canada and the United States to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem.

A 1987 Protocol, updating the Agreement, promised that the countries would deal more strictly with such diverse pollution sources as toxic chemical fallout from the air, leaking chemical waste dumps and polluted runoff from farm fields, industry and city streets. And the two nations agreed to develop Remedial Action Plans to bring business people and citizens into the process of helping to clean up the Areas of Concern.

In 1987, Canada, the United States, Ontario and New York also signed a Declaration of Intent on Pollution of the Niagara River. This document committed the four governments to reduce specific chemical discharges to that river by at least half by 1996. This agreement covers a number of persistent toxic chemicals that have been coming from industries that discharge waste water directly into the Niagara and those that send their wastes into municipal sewer systems, which later discharge into the river. Some municipal systems have carbon filtration systems to trap organic chemicals. The Niagara agreement also covers wastes seeping into the river from leaking dumps.

Large Municipal Wastewater Treatment Plant

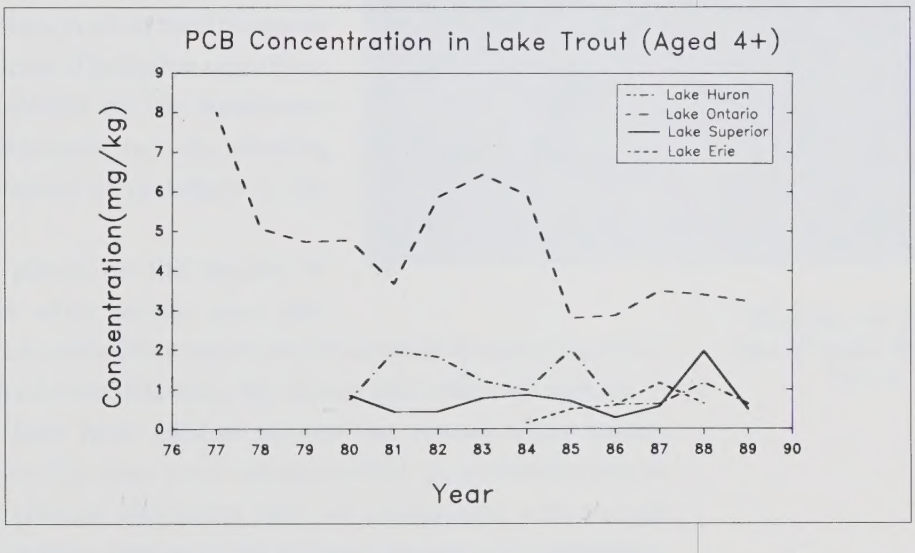
Pollution control has not been cheap. Federal, state, provincial and municipal governments in the United States and Canada have spent tens of billions of dollars on sewage treatment systems alone during the past 20 years. This sum has been mainly on "conventional" sewage treatment, that deals with human wastes and phosphorus from detergents. Sewage treatment plants are not capable of completely removing and disposing of the toxic chemicals that flow through them. They trap some of the chemicals but these pollute the sewage sludges or are released into the air.

Controls on toxic chemical pollution are harder to price. In a number of cases, they involved orders to stop producing certain products. In other cases, they required many millions of dollars of spending by industries to change processes or to build pollution control devices. In the future, they will require very large sums to clean up chemical wastes in leaking dumps, leakage on current and former industrial sites, and contaminated sediments on harbor and river bottoms. Cost estimates are not complete, but the indications are that the cleanup of toxic dumps and polluted harbor and river bottoms will likely cost billions of dollars. As they begin to understand the true costs of pollution, industries are now making greater attempts to catch pollutants before they escape beyond the plant gate. And there are signs that industries are looking at new processes that will create fewer hazardous substances in the first place.

Trends in Pollution Discharges and Levels

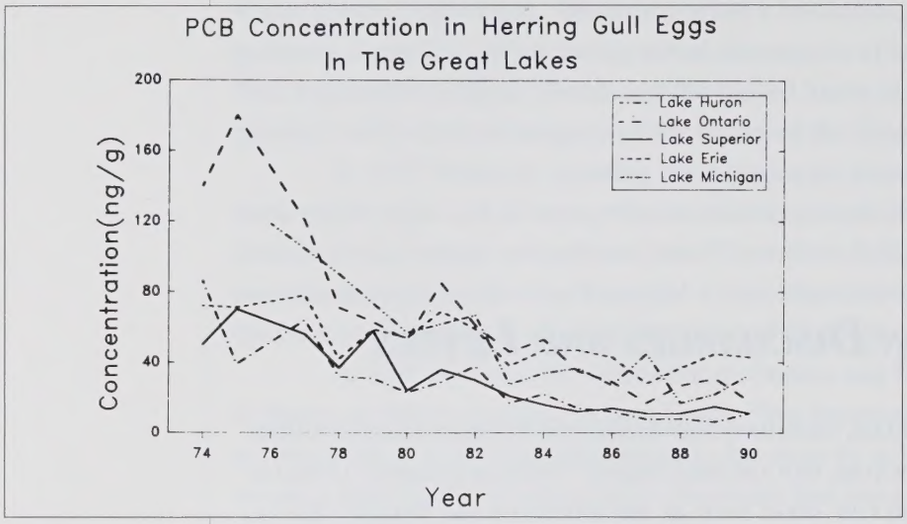
As a result of control programs, there have been reductions in the levels of a number of toxic chemicals in Great Lakes water, fish and bird tissues. Tests of chemical levels in Great Lakes sediments, particularly in areas such as the mouth of the Niagara River, indicate that toxic chemical pollution rose as industry grew after about 1940. The greatest inputs of arsenic, cadmium, lead, mercury, DDT, dioxins, furans and other industrial chemicals and pesticides took place in the 1960s and 1970s. Since then, there have been major declines in some key pollutant levels.

One example of the amount of reduction that can be achieved is in the Niagara River, which has long been identified as one of the most contaminated areas of the Great Lakes. The New York Department of Environmental Conservation reported that the daily discharge of priority pollutants from 29 U.S. municipal and industrial sources was reduced by 80 per cent during the period 1981-82 to 1985-86. Consequently, the load was reduced from 2,745 pounds (1,245 kilograms) to 544 pounds (247 kilograms) per day.



Pollution Trends: PCB Concentrations in Lake Trout.

The trends for most contaminants in the Great Lakes ecosystem were steadily downward for a number of years following the peak of the early 1970s. In recent years the levels of certain chemicals in wildlife have levelled off and pollution still remains above acceptable ambient levels in a number of cases. The levelling off indicates both that toxic



Pollution Trends: PCB Concentrations in Herring Gulls

chemicals are still being added to the lakes and that old chemicals are remaining in the ecosystem. This situation offers us a great challenge. Many of the easy and relatively cheap steps have been taken. If we want to further reduce the risk to the ecosystem, we will have to make much greater efforts.

Current Approach to Cleaning up the Lakes

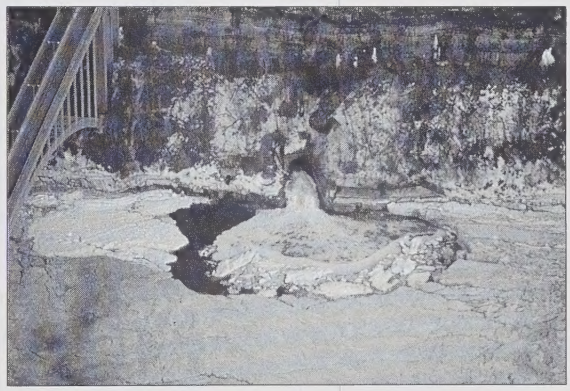
Traditional approach

Control of toxic substances is not necessarily undertaken in the same way in the two countries or in any of the individual jurisdictions. In the United States, toxic substances are controlled through the authority of the 1972 Clean Water Act. Direct discharges of toxic substances are permitted so long as they are in non toxic amounts. These amounts are calculated in two ways. The first is based on an application of the best technology that is practicable or available for the treatment of each pollutant from over 250 categories of industries. The second is based on application of the capacity of a receiving water to assimilate a substance.

The assumptions and methods for calculating wasteload allocations vary from state to state. Some states may consider all sources of a substance in an entire basin, while others may allocate loadings on the basis of individual discharges. Restrictions on effluent discharges can be expressed in concentrations and/or in mass limits.

Spills and dumping of chemicals in and around industrial plant sites may result in nonpoint sources of pollution since these sources would not normally be collected by the wastewater system. The application of best management practices, resulting in the collection, treatment and disposal of pollutants in the wastewater system may be required.

Restrictions may also be placed on the toxicity of municipal or industrial wastewaters when several toxic substances are present. In cases where the toxicity of the wastewater exceeds the bioassay standard, detailed investigations may be undertaken to determine the source and reduce its toxicity.



Wastewater Discharge to the Niagara River, Niagara Falls, N.Y.

These various techniques have been used to protect and restore water quality throughout the United States. However, for some toxic substances that are persistent and can be bioconcentrated, the calculated effluent allocations may be unattainable with current wastewater treatment technology. For these persistent and bioconcentrated toxic substances, their use and release must be prohibited in order to eliminate the effects they have caused.

In the Canadian system, the focus is on the provincial program. The Province of Ontario, through its legislation and provincial Water Quality Objectives, issues approval certificates with conditions to dischargers. These conditions have traditionally addressed the more common contaminants, but through the new Municipal Industrial Strategy for Abatement (MISA) will contain requirements for the more exotic contaminants present in the discharge.

In addition, the province, through the Ministry of the Environment, issues orders under its legislation requiring municipalities, industries and individuals to take steps to control emissions to air, water or land. These orders may be appealed by their recipients, but are enforceable once issued or following a favourable appeal board ruling.

The ecosystem approach

For years there have been calls for a new approach to pollution control, particularly to the control of persistent substances that remain toxic in the environment for months or years. One way of viewing the Great Lakes basin is to think of it as an ecosystem, in which political boundaries mean nothing to the movement of pollutants once they are released. The ecosystem is defined in the 1978 Great Lakes Water Quality Agreement as the interacting components of air, land, water and living organisms, including humans. The ecosystem approach recognizes that all components of the environment are interconnected and that pollution released in one area can cause problems in another. This concept requires everyone who can have an impact on the environment to recognize and reduce impacts. In practice, it requires people to avoid actions that can even indirectly lead to contamination of the lakes.

Virtual elimination and zero discharge

The 1978 Water Quality Agreement brought important commitments from the United States and Canada for the control of toxic pollutants.

- *It said that the two nations, "agree to make a maximum effort to develop programs, practices and technology necessary for a better understanding of the Great Lakes Basin Ecosystem and to eliminate or reduce to the maximum extent practicable the discharge of pollutants into the Great Lakes System."*
- *It said that it is the policy of the two nations that: "The discharge of toxic substances in toxic amounts be prohibited and the discharge of any or all persistent toxic substances be virtually eliminated."*

The Agreement said that "regulatory strategies for controlling or preventing the input of persistent toxic substances to the Great Lakes System shall be adopted in accordance with the following principles:"

- *"The intent of programs specified in this annex is to virtually eliminate the input of persistent toxic substances..."*
- *"The philosophy adopted for control of inputs of persistent toxic substances shall be zero discharge."*

There have been many discussions about exactly what those phrases mean. A number of people interpret them to mean that there should be no use of persistent toxic substances, because experience has shown some will almost always leak or be spilled in the environment. An example of applying the principle of zero discharge to its fullest would be to impose a ban on the manufacture and use of a hazardous substance. The bans could even be applied to chemicals which are made in the United States or Canada and exported to other nations, if those chemicals could blow into the Great Lakes basin on air currents.

The Virtual Elimination Task Force of the IJC, said that: "Zero discharge means elimination of all inputs, whether from direct discharges into waterways or the air, indirect discharges such as agricultural and urban runoff, or inadvertent discharges, such as leaking landfills or reactivation of contaminated sediment." It went on to say that: "The guiding assumption is that all sources of persistent toxic substances must be eliminated so there will be no opportunity or availability for the chemicals to enter the ecosystem. Zero discharge,

therefore, implies zero availability."

In practice, governments in both nations have banned the manufacture or use of very few chemicals, but they try to restrict the use and discharge of hazardous substances. This policy means that chemicals can be produced and used, but under very tight controls. However, it leaves the possibility that chemicals will escape from factories during their manufacture or storage, will be released into the environment by a user, or will be disposed of in a way that lets them escape.

There is another important aspect to the interpretation of zero discharge. Because pollution is now present in the water, it will be taken in by industries that draw from the Great Lakes, and discharged later. The term zero discharge should be interpreted to mean zero pollution added to the discharge as it goes through a system.

Cleaning up in the future

Natural processes

To a certain degree, nature will cleanse the environment after we stop adding more pollution. Some chemicals will be broken down into less harmful substances by sunlight and bacteria. The natural process of sedimentation will eventually bury others deeply enough in the bottom sediments of the lakes to put them out of reach of living creatures. Some chemicals will be buried with the bodies of those who absorbed them.

Part of the volatile chemical load will also leave the Great Lakes basin, though it may have harmful effects elsewhere. Volatile chemicals evaporate into the sky where some are broken down by sunlight and others are blown away from the Great Lakes basin. Some chemicals will be flushed down the Great Lakes - St. Lawrence system into the Atlantic Ocean. This movement will not happen instantly. It can take up to 230 years for water to move from the westernmost end of Lake Superior to the ocean, but because some toxic chemicals persist in the sediments for centuries, it is not guaranteed that the chemicals will be flushed out.

Both the Canadian and Ontario governments have announced regulations to further reduce industrial discharges.

Government cleanup projects and plans

Federal, state and provincial governments are periodically announcing new plans and laws for reducing the toxic chemical load in the ecosystem. Included are regulations limiting the amount of pollution that can be discharged by industry, and funds to clean up contaminated sites. Both Canada and the United States have announced programs aimed more strongly at pollution prevention.

In 1989, the Canadian government announced it would spend $125 million over five years under the Great Lakes Action Plan. This amount includes a $55 million fund to clean up contamination that is a federal responsibility in the 17 Areas of Concern that involve Canada. Funds will be used to deal with old wastes on federally-controlled lands, such as harbors and areas where no previous owner can be made to clean up the pollution. The fund will help to pay for technology demonstration projects to find the best ways of cleaning up degraded areas.

Funding will also cover scientific work needed to ensure that projects do clean up the lakes and to monitor the ecosystem to make certain that it stays clean. This work includes a major study on what toxic chemicals in the Great Lakes ecosystem are doing to human health. Money is also earmarked for demonstration of clean technologies and education programs on how to prevent pollution. In 1991, Environment Canada announced the creation of a pollution prevention centre for the Great Lakes to offer expertise to the public.

Over a period of years, Ontario has been phasing in a water pollution control plan that calls for virtually zero discharge of persistent toxic substances. When fully implemented, the

Municipal-Industrial Strategy for Abatement (MISA) is to regulate about 200 major industries that discharge directly into the Great Lakes or tributaries. MISA will also cover 12,000 industries that discharge into 400 municipal sewage treatment plants by setting limits on what the sewage treatment plants can release to waterways. Industries are to reduce discharges, using the best available pollution control technology that is economically achievable.

In 1990, the Canadian government released draft national regulations for pulp and paper mills, including those on the Great Lakes. These regulations are aimed at reducing discharges of a wide range of harmful chemicals and are to virtually eliminate dioxin and furan discharges from pulp and paper mills.

The United States government, particularly the Environmental Protection Agency (EPA), and the eight Great Lakes state governments, have spent large amounts of money on Great Lakes cleanups. The EPA Regions II, III and V offices, which are responsible for the U.S. side of the Great Lakes, and the EPA Great Lakes National Program Office have spent $11 billion since 1972. Most of this money has gone into building sewage treatment plants.

Under the U.S. Clean Water Act, states have been implementing control programs, based on best available technology. Such programs treat chemical wastes before they are discharged into municipal sewers and they reduce pollution levels in water released directly into lakes and rivers. The Clean Water Act uses National Pollutant Discharge Elimination System permits, which set specific limits for discharges of various pollutants.

The EPA has identified the Great Lakes as one of the agency's top priorities and wants them to be a laboratory to demonstrate ways of reducing and preventing pollution, and protecting both ecological integrity and human health.

In the spring of 1991, William Reilly, the Administrator of EPA, announced the U.S. Pollution Prevention Action Plan for the Great Lakes. The plan includes four initiatives to accelerate restoration and protection of the Great Lakes. The program will assist auto makers in reducing pollution, launch a pilot program on reducing urban runoff, host an international pollution prevention symposium in Traverse City, Michigan in September 1991, and develop a program to protect Lake Superior from toxic pollutants. The action plan sets targets for pollution reductions, including a 50 percent drop in the release of 17 contaminants, between 1988 and 1995. The budget request for EPA resources to be devoted to the Great Lakes basin is approximately $44 million for fiscal year 1992, an increase of $18.5 million from fiscal year 1991.

Two new laws adopted by Congress in 1990 could reinforce federal and state authority for achieving virtual elimination of toxic pollution of the lakes. Part of the U.S. Clean Air Act allows the regulation of pollutants that fall on the lakes. The Great Lakes Critical Programs Act adds a specific requirement that Environmental Protection Agency programs conform to provisions of the Great Lakes Water Quality Agreement.

Governors of the eight Great Lakes states have made a number of commitments as a group to Great Lakes protection. In 1986, the governors signed the Great Lakes Toxic Substances Control Agreement. Since then, Ontario and Quebec have signed a memorandum of understanding, which joins them to the Agreement with its six principles. Those principles include a statement promising to reduce toxic discharges to the maximum extent possible. By mid-1991, the governors had put $50 million into a $100 million endowment to fund Great Lakes protection programs. Interest from the fund is providing grants for a number of projects, including citizens' participation in Remedial Action Plans, studies on the health effects of contaminants, public information programs on the risk from eating contaminated fish and

research into sources of air pollution affecting the lakes.

In April, 1991, the governors released a Pollution Prevention Challenge. It is aimed at getting government, business and citizens to co-operate on pollution control programs. The governors have promised a number of actions that are to make pollution prevention easier and more rewarding for business.

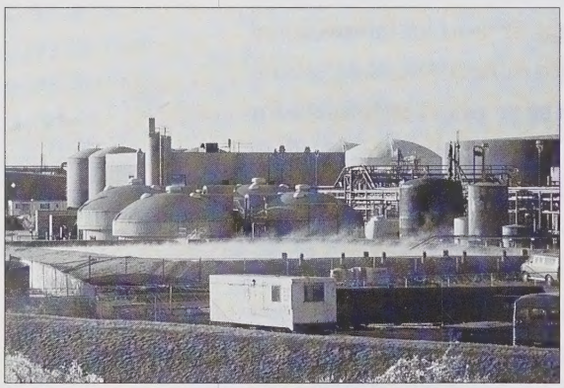
Pollution reduction plans are having an effect in a number of highly contaminated areas. The case of the Niagara River shows the kind of reductions that can be achieved. Four-fifths of the cuts in the early 1980s came from regulations under New York State's Pollutant Discharge Elimination System permits, better pretreatment of waste discharges into the municipal sewer system and better industrial practices to reduce leaks and spills. The rest of the cleanup resulted from plant closings and process shutdowns.

Industry

Our waters will never be cleaned up without a major effort by industries. Until a few years ago most business leaders gave few public signs that they felt a pressing need to alter the long-standing practice of simply diluting waste discharges in water. The approach of a growing number of industrialists is changing, and corporate leaders are now talking about major reductions or the elimination of toxic discharges.

Industries have spent hundreds of millions of dollars on pollution controls around the Great Lakes. Much of this expenditure has been on what is often called end-of-pipe technology-- equipment added to try to capture toxic chemicals before they escape into the water and air. Money is also being spent on building physical barriers and containment systems to reduce leakage and spills into the lakes.

Some of the most promising efforts directed at pollution reduction are going into new products and processes. This approach means changing the way old products are made and creating new products, to use and produce less hazardous materials. A number of the new manufacturing processes are called closed-loop systems because they are designed not to release any harmful substances into the environment. The chemicals are literally kept in a closed system in the factories.



Wastewater Treatment Plant - Dow Chemical, Sarnia, Ontario

One example of a company that has made significant changes is located along the St. Clair River, an Area of Concern. Since 1985, Dow Chemical Canada Inc. has cut the amount of 43 priority pollutants escaping from its Sarnia complex into the St. Clair River from 350 kilograms to about eight kilograms a day.

In 1989, Dennis Lauzon, a Dow vice-president, said: "Our goal is to virtually eliminate spills and discharges from our plant site to the St. Clair River. To make this happen we are committed to separate our site from direct contact with the river." This goal will require 100 projects on the site, which has 13 manufacturing plants, and much of the work will involve capturing and treating pollution before it reaches storm sewers on the property. The plan is to virtually eliminate spills of harmful discharges by or before the year 2000. In May, 1990, Dow separated the chemical cycle of its plant at Varennes, just east of Montreal, from the St. Lawrence River and is recycling the water that is used in the factory.

Remedial Action Plans

The Water Quality Board developed the concept of Remedial Action Plans (RAPs) to rehabilitate Areas of Concern around the lakes. In 1987, Canada and the United States incorporated the RAP concept into the Protocol to the 1978 Great Lakes Water Quality Agreement. Traditionally, hazardous waste cleanup plans have been designed by governments, sometimes with periodic consultation with other groups and individuals. RAPs are a breakthrough in cleanup programs in that they formally bring governments, businesses, environment groups and individual citizens to the table on a long-term basis to discuss how to restore polluted areas in their regions to a healthy state. The aim is to focus local attention on defining problems and finding solutions, based on what residents want for their waters.

There are already hundreds of people involved in RAP public advisory committees and thousands more who are keeping in touch with the RAP process. By early 1991, a stakeholder group, basin committee, citizen advisory committee or comparable group broadly representative of environmental, social and economic interests, had been established in 33 of the 43 Areas of Concern. One advantage of the RAP process is that it allows very long term planning, longer than the average political term of office and longer than many government funding programs. The work has been ongoing for several years and will continue for many years in the future. In a number of RAP programs, detailed project outlines exist, but work has not yet commenced on major cleanups. RAP committees for the Rouge River and Fox River have set the goal of re-establishing healthy ecosystems by the year 2005. In the case of Green Bay, the target is 2000.

Rendering waters fishable in urban areas is a major challenge facing RAP participants

Costs of Cleaning up our Great Lakes

In some cases, old pollution can be dug up from hazardous waste sites or dredged from polluted harbors. It can be destroyed by incineration, chemical or biological means, or by other technologies. In some cases, it can be stored pending safe destruction. The cleanup ahead will not be cheap. Reports from the Northeast-Midwest Institute, U.S. General Accounting Office and a study by scientists from the Canada Centre for Inland Waters calculate that it will cost several billion dollars to clean up toxic hotspots around the lakes. Much of the cost involves removal and destruction of pollutants in sediments in river bottoms and harbors and attempts to stop leakage of toxic chemicals from underground dumps.

In addition, our industries will have to spend hundreds of millions, if not billions, of dollars more in re-tooling many factories and building containment systems to stop pollution at its source. Municipal governments will have to spend large amounts to prevent hazardous chemicals from slipping through their sewer systems.

We must further control the release of air pollution in the United States and Canada and we must negotiate international agreements to control pollution that blows in from other nations. This action may require subsidizing pollution controls in poor nations in our common interest. This principle has already been adopted in the case of protecting the ozone layer from chemical attack.

Test case- decontamination of Toronto Harbor Commission lands

The Toronto Harbor Commission has announced that it will start a test program to decontaminate soils on industrial lands that were used for coal storage and an oil refinery. The project will start with a shipment of soil to a plant in Europe, where it will be chemically "washed" to reduce pollution. The Commission has said that if the experiment is successful, a treatment plant will be built at the harbor. The Harbor Commission considers that the cleaned-up land can then be developed commercially, thus paying for remediation. The Commission estimates that this cleanup could cost $320 million.

Test case - decontamination of Waukegan Harbor

In the case of Waukegan Harbor, Illinois, just north of Chicago, over 150 tons of PCBs have escaped from industry into the harbor in the past. As part of a settlement between the federal and state governments and Outboard Marine Corp., PCBs are to be excavated from the harbour, starting in 1991. Starting in 1992, the PCBs are to be extracted from the sediments, using a heating process, and sent for proper disposal. The U.S. Environmental Protection Agency has put the cost of removing the contamination at $19 million.

The Challenge Ahead

GOVERNMENTS FACE THE DAUNTING TASK OF CO-ORDINATING POLLUTION CONTROL PROGRAMS AMONG TWO NATIONAL, EIGHT STATE, ONE PROVINCIAL AND HUNDREDS OF MUNICIPAL GOVERNMENTS, OFTEN WITH DIFFERENT ENVIRONMENTAL LAWS. IT REQUIRES AN UNDERSTANDING OF THE ECOSYSTEM APPROACH BY THOUSANDS OF OFFICIALS IN HUNDREDS OF SPECIALIZED AGENCIES, COMMISSIONS, BOARDS AND GOVERNING BODIES, MANY OF WHICH DO NOT HAVE ENVIRONMENTAL PROTECTION AS THEIR TOP PRIORITY.

THE DISCHARGE OF TOXIC MATERIAL IS STILL ALLOWED UNDER CURRENT PERMITS, MOST OF WHICH ARE STILL BASED ON THE PRINCIPLE OF DILUTION OF WASTE DISCHARGES.

Even though laws in Canada and the United States have reduced the discharge of a number of toxic chemicals, they have not virtually eliminated the release of persistent toxic substances. In addition, chemicals still seep into the lakes from diffuse sources and arrive as toxic fallout.

Industries face a major task in better understanding their environmental impacts, and in changing processes and products to virtually eliminate the discharge of persistent toxic chemicals. This task involves not only the major industries, which have or can hire environmental experts, but thousands of small companies, most of which do not have the staff or finances to develop or implement sophisticated environmental plans. They will need to co-operate and probably to receive technical advice from larger companies.

Individuals must go through the same process of analyzing their environmental impacts. It is individuals who run governments and companies and who shape their policies. It is individuals who choose whether or not to buy products made from or containing toxic substances and to dispose of them in safe or unsafe ways.

How can we do a better job of cleaning up?

Our industrial society, including its governments, was not designed to anticipate and prevent serious environmental problems. It has generally operated on the principle that when problems are found, society will react and cure them. Pollution of the Great Lakes and many other environmental problems have shown that it is almost impossible to recapture persistent, toxic pollutants once they have been dispersed in the environment.

Business people can play a vital role in pollution prevention by getting their companies and business associations involved in reducing pollution and recycling

For several years, expert groups have been developing a new definition for the kind of industrial society that we need in order to adequately protect our environment. One term that has been adopted by a number of governments, businesses and environmental groups is environmentally-sustainable economic development. Often it is simply called sustainable development. The term was popularized by the 1987 report of the World Commission on Environment and Development, the Brundtland Commission. This UN-appointed body defined sustainable development as that which "meets needs of the present without compromising the ability of future generations to meet their own needs."

To reach sustainable forms of development and living we will have to make significant changes in the way we produce energy, use cars, farm, produce and handle oil and chemicals, and manage our forests. We will have to stop or reduce not only the direct discharges into our waters, but find ways of stopping the insidious spills, leaks, runoff and illegal dumping from millions of diffuse sources.

We will have to develop towns and cities in ways that reduce the daily discharge of wastes into the waters. In the case of the Great Lakes and St. Lawrence basins, this action means preventing pollution in the future and restoring a seriously damaged ecosystem by cleaning up the mess created by years of carelessness and neglect. This process has been referred to as "sustainable re-development."

Sustainable development means setting goals for the kind of ecosystem we want for ourselves and our children. To put it in simple terms, how clean do we want it? Do we want to be able to swim virtually anywhere, eat fish without fear of contaminants and drink the water with less risk from contamination? What future do we see for other species? This is the kind of decision-making process that is now taking place in a number of towns and cities around the lakes under the Remedial Action Plans.

There are a number of obvious measures that can be taken, but they involve costs. We can do a better job of handling and storing hazardous materials that keep leaking into the waters. Industries can install more closed-loop processes that minimize the release of hazardous wastes. They can switch to less hazardous products and use less toxic material. If we want zero discharge of certain substances, then we will probably have to stop making them altogether. We may have to give up certain products that we now use and pay more for others.

We can improve farming and land development practices to prevent pollution from washing off the land. These improvements will involve less use of certain pesticides, safer use of others and land management techniques that reduce the amount of polluted runoff. Often improvement means maintaining more marshes and vegetation along shorelines to provide natural filters for water. It can mean the redesign of drainage systems to reduce the amount of water that is flushed rapidly off the land.

We can do a much better job of educating and training people in government and industry to understand the effects of their decisions and actions on the environment. Such people will require education on how ecosystems work and how actions in one part of the environment can have impacts over long distances and time frames in natural systems.

As individuals, we must realize that any waste we put down the drain or into garbage will sooner or later pollute the environment. When chemicals go down the drain, they add a chemical load to somebody's source of drinking water. We can stop pouring old paints and waste chemicals down our sinks and throwing batteries and chemicals into the garbage. In many areas, these products can be removed for proper disposal by hazardous waste pickups provided by municipal, provincial or state governments.

If we are going to have environmentally-sustainable lifestyles, we will have to choose techniques, technologies and products that have a lower total impact on our environment. We can reduce our use of electricity and heating fuel at home, buy fuel-efficient cars and use them less often. These actions will cut the discharge of many toxic pollutants from factories, electric generating stations and exhaust pipes. We can reduce our use of toxic chemicals in the home and garden and buy fewer throwaway products.

One way to get a sense of our individual responsibility is to do a waste inventory at home, looking for hazardous products and finding ways of reducing their use or substituting less toxic materials or techniques. It is worth remembering that most toxic products were only brought onto the market in the last generation, and our parents operated without them. There is a flood of information on how individuals can protect the environment. The material is in books, pamphlets and newsletters from environment groups, governments, businesses and in bookstores.

Individuals can also play a direct role in helping to clean up our Great Lakes by becoming involved in Remedial Action Plans for polluted areas. Citizens also have the power of electors and consumers. The way to let people know what changes you want is to write or phone your elected officials and to let manufacturers know what you like and don't like about their products.

RECOMMENDATIONS

THE PARTIES HAVE PREVIOUSLY AGREED TO REGULATORY STRATEGIES AND PROGRAMS TO VIRTUALLY ELIMINATE THE INPUT OF PERSISTENT TOXIC SUBSTANCES INTO THE GREAT LAKES ECOSYSTEM, IN ORDER TO PROTECT HUMAN HEALTH AND LIVING AQUATIC ECOSYSTEMS AND THE HUMAN USE THEREOF. THE PHILOSOPHY ADOPTED FOR THE CONTROL OF INPUTS OF PERSISTENT TOXIC SUBSTANCES SHALL BE ZERO DISCHARGE.

• The Water Quality Board confirms that many of these persistent toxic substances are so troublesome as to require clear and absolute bans. Severe restrictions to date have produced significant reductions of some of these substances in the Great Lakes ecosystem, including its fish, wildlife, water and sediments. But experience shows that these reductions are not as comprehensive as we now think necessary. Studies suggest that these substances actually have or threaten to have continuing important, if very subtle effects, on human health and wildlife, even in very low concentrations.

The Parties have not yet adequately dealt with the manufacture, import, use, storage, transportation and disposal of these substances. The Board recommends that this situation be rectified as a matter of urgency. Actions should target six of the persistent toxic substances on the list of Critical Pollutants prepared by the Board in its 1985 report. These are: PCBs, DDT, dieldrin, toxaphene, mirex and hexachlorobenzene.

CORMORANT WITH BIRTH DEFECTS CAUSED BY PERSISTENT TOXIC SUBSTANCES

• Some of the sources of the Critical Pollutants in the 1985 Board report lie outside the Great Lakes basin. Recognizing the increasing importance of out-of-basin sources in the contamination of the Great Lakes with persistent toxic substances, the Parties should take a leadership role in promoting the elimination of the use of these substances, world-wide.

Other substances have been confirmed as present in the Great Lakes basin. The extent of their potential for harm is not clear, but it is likely that some ought to be considered for absolute bans.

The Parties must identify those chemicals that should be added to the list of substances which should be banned. In order to accomplish this task, the Parties jointly need to develop a process with a fixed timetable and schedule. The 1987 Protocol to the Great Lakes Water Quality Agreement calls for the Parties to establish a list of critical toxic substances, [List No. 1, Annex 1].

However, the Board thinks that the definition of persistent toxic substances in the Agreement is too general. The Board also thinks the criteria for this list are too general and do

not reflect the high potential for certain substances to cause harm. On the basis of the weight of evidence, the Board thinks that there are factors which should be included in any criteria used for assigning priorities to substances. These include bioaccumulation, persistence, exposure potential and a range of toxic end points that is broader than cancer. These toxic end points include developmental effects in the offspring of exposed adults.

• The Board recognizes that the Parties and other international bodies, such as the Organization for Economic Co-operation and Development, have processes for evaluating the potential hazards of new substances. The Board recommends that the Parties establish a new joint approval process for new substances proposed for the marketplace when those substances might have toxic effects on the Great Lakes ecosystem. This process could cover the manufacture in Canada and the United States and the distribution and sale of such products in any market. This approval process should embody such factors as bioaccumulation, persistence, exposure potential and a broad range of toxic end points, including cancer and developmental effects. The approval process should place the burden of proof on the manufacturer and it should be open to public scrutiny.

Priorities of the Water Quality Board

In June, 1991, the Water Quality Board developed a list of 15 priority issues that need to be addressed in order to achieve the Board's vision for a healthy Great Lakes ecosystem. They are:

- The next Great Lakes Water Quality Agreement
- Risk and injury assessment and management
- Regulatory regimes-- current and emerging
- Integrated approaches to watershed and shoreline management
- Groundwater management practices
- Role of/how to involve municipalities in the management and clean-up of the Great Lakes
- Role of industry in managing the Great Lakes basin
- Role of the agricultural and forestry sectors in managing the Great Lakes basin
- Evaluation of education and information policies and programs in the Great Lakes basin
- Applying sustainable development in the Great Lakes basin
- Control options for out-of-basin loadings
- The real public health issues in the Great Lakes basin; are standards consistent?
- Water quality-- tourism and recreation in the Great Lakes basin
- Fish and wildlife restoration-- competing visions
- Relationships between water quality and water quantity

Long term goals

We who live in the Great Lakes - St. Lawrence ecosystem have a responsibility to restore and protect the greatest source of fresh water on the planet. We have a duty to protect it for ourselves, our children and other species of life. We have started the job, but there is still a lot of work to do. It is important to set a series of milestones so that we can see progress being made.

Most people want the lakes to be drinkable, swimmable and fishable. We have seen the green slime vanish from most of the areas that suffered from excess phosphorus pollution in the past 30 years. A number of fish that were once unsafe to eat can now be consumed. Most bird species that were failing to reproduce are now hatching young, though some are still deformed.

There are a number of signs to look for in a campaign for decontamination of our ecosystem. One would be the lifting of all bans on the consumption of fish. Another would be to find no pollution-caused deformities in wildlife, especially at the top of the food chain. We should see healthy wildlife that can reproduce and thrive everywhere. One worthy symbol of restoration could be healthy populations of bald eagles, the top predator, living all around the lakes. If they are healthy, then we will be approaching an ecosystem virtually free of persistent toxic substances.

This is our vision of the Great Lakes of the future. This is what we are striving to achieve.

The Great Lakes watershed is a clean, safe environment where life forms exist in harmony. People take pride in the Great Lakes. We share and live an ethic which recognizes that environmental integrity provides the foundation for a healthy economy. We are secure in the knowledge that the fish and wildlife are healthy and the water can be enjoyed by all. We understand our responsibility for ensuring a self-sustaining Great Lakes ecosystem. This is the example we set for the rest of the world and the legacy we leave our children.

Bald Eagle in flight

APPENDICES

Reading List

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Page 37 - National Wildlife Federation

Page 45 - Wilson G. Portt

Contact List

International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario N9A 6T3
or
P.O. Box 32869
Detroit, Michigan 48232

Canadian Government
Great Lakes Environment Office
Environment Canada, Ontario Region
6th Floor, 25 St. Clair Avenue East
Toronto, Ontario M4T 1M2

United States Government
Environmental Protection Agency
Great Lakes National Program Office
230 South Dearborn Street
Chicago, Illinois 60604

Ontario
Ontario Ministry of the Environment
1 St. Clair Avenue West
Toronto, Ontario M4V 1K6

Illinois
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Indiana
Indiana Department of Environmental Management
105 South Meridian Street
Indianapolis, Indiana 46225

Michigan
Michigan Department of Natural Resources
P.O Box 30028
Stevens T. Mason Building
Lansing, Michigan 48909

Minnesota
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, Minnesota 55155

New York
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York
12233-3500

Ohio
Ohio Environmental Protection Agency
P.O. Box 1049, 1800 WaterMark Drive
Columbus, Ohio 43266

Pennsylvania
Pennsylvania Department of Environmental Resources
P.O. Box 2063
3rd and Locust Streets
Fulton Bank Building F
Harrisburg,Pennsylvania 17105

Wisconsin Department of Natural Resources
P.O. Box 7921
101 S. Webster Street
Madison, Wisconsin 53707

Council of Great Lakes Governors
35 East Wacker Drive, Suite 1850
Chicago, Illinois 60601

Great Lakes Fishery Commission
1451 Green Road
Ann Arbour, Michigan 48105

Environment Groups

Great Lakes United
State University College at Buffalo
Cassety Hall, 1300 Elmwood Avenue
Buffalo, NY 14222
or
Canadian Address:
P.O. Box 548, Station A
Windsor, Ontario N9A 6M6

National Wildlife Federation
Great Lakes Office
802 Monroe
Ann Arbor, MI 48104

Canadian Institute for Environmental Law and Policy
517 College Street, Suite 400
Toronto, Ontario M6G 4A2

The Center for the Great Lakes
435 N. Michigan Avenue, Suite 1408
Chicago, IL 60611
or
320-1/2 Bloor Street W., Suite 301
Toronto, Ontario M5S 1W5

Great Lakes Tomorrow
720 Bathurst Street
4th Floor, Unit 3
Toronto, Ontario M5S 2R4

Pollution Probe Foundation
12 Madison Avenue,
Toronto, Ontario M5R 2S1

World Wildlife Fund
The Conservation Foundation
1250 Twenty-fourth Street, N.W.
Washington, D.C. 20037

Council of Great Lakes Industries
c/o Detroit Wayne County Port Corporation
174 South Clark Street
Detroit, Michigan 48209 U.S.A.

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